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International University-Industry Knowledge Transfer

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for doctoral or equivalent academic degree.

Merle Küttim

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Rahvusvaheline ülikooli ja ettevõtete vaheline teadmussiire

MERLE KÜTTIM

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Contents

List of Publications

The thesis structure entails four articles. The author is an only author in one of the articles, the first author in one and the second author in the remaining two articles.

The list of author's publications, on the basis of which the thesis has been prepared includes:

I Kalantaridis, C.; **Küttim, M**.; Govind, M.; Sousa, C. (2017). How to commercialise university-generated knowledge internationally? A comparative analysis of contingent institutional conditions. Technological Forecasting & Social Change, 123, 35−44. 10.1016/j.techfore.2017.06.013. (ETIS 1.1)

II **Küttim, M**. (2016). The role of spatial and non-spatial forms of proximity in knowledge transfer: a case of technical university. European Journal of Innovation Management, 19(4), 468−491. 10.1108/EJIM-12-2015-0126. (ETIS 1.1)

III **Küttim, M**., Kiis, A., Sousa, C. (2020). Brokers in Biotechnology and Software Networks in EU Research Projects. TalTech Journal of European Studies, 10(1), 195−231. 10.1515/bjes-2020-0010. (ETIS 1.1)

IV Govind, M.; **Küttim, M**. (2016). International knowledge transfer from university to industry: A systematic literature review. Research in Economics and Business: Central and Eastern Europe, 8(2), 5−25. (ETIS 1.2)

Author's Contribution to the Publications

Contribution to the papers in this thesis are:

I The author of the thesis is the second author of the article. The first author developed the theoretical framework of the article through discussions with co-authors. As the article covered four country contexts, each author was responsible for gathering and analysing data in their respective country, and the author of the thesis did it for Estonia. The author of the thesis developed the survey instrument (interview guides) for the five target groups included into the study (the same that were used in Article II). The author of the thesis also wrote the methodology section of the article. The first author elaborated the conclusions and propositions and contributions through discussions with co-authors.

II The author of the thesis is the only author of the article. The author was responsible for developing the theoretical framework of the study, designing the data collection instrument (interview guides) for the five target groups included into the study, collecting and analysing data, presenting the results, conclusions and contributions, and revising the paper based on reviewers' comments.

III The author of the thesis is the first author of the article. The author is responsible for developing the theoretical framework through discussions with the co-authors, for collecting and analysing the data and for the presentation of results. The methods of data analysis and main findings and contributions of the study were discussed and refined further in cooperation with the co-authors. The authors is also responsible for revising the paper based on reviewers' comments.

IV The author of the thesis is the second author of the article. The author is responsible for conducting the literature search with selected key words in the selected databases, conducting data analysis in parallel with the first author, and writing parts of the paper (abstract, theory, first part of results), and revising the paper based on reviewers' comments.

Introduction

University–industry linkages are increasingly being established over geographical distances and across national boundaries, as the central locus of innovation has become international and dependent upon linkages between different types of organisations and sources of knowledge (Heitor, 2015). This type of knowledge transfer is enabled by the low cost and global spread of ICTs, which allow for more distributed innovation processes (Schwaag Serger & Wise, 2010) and the offshoring of corporate R&D facilities (Karlsson et al., 2006). The outcome is increased international technological collaborations, often as part of global innovation networks (Gassler & Nones, 2008; Li, 2010). This enables universities to establish and participate in global networks and to pursue international markets to withstand global competition (Garrett-Jones & Turpin, 2012). For their part, enterprises are able to be more competitive in international markets by responding to progress in science and technology (Mason & Wagner, 1999) and engaging in new product development (Santoro et al., 2017). They can also mitigate the risks of spatial and cognitive lock-in (Petruzzelli & Murgia, 2019) and engage in new path development (Petruzzelli & Murgia, 2019; Trippl et al., 2018).

The research problem of the thesis is related to the notion that the transfer of knowledge across institutional boundaries, like countries and sectors, involves actors with different institutional logics and types of capital (Scott, 2015). As the locations of actors in different countries influence the prevailing regulatory regimes as well as a range of other characteristics, like language and religion (Ionascu et al., 2004), national institutional differences result (Malik & Yun, 2017). Regarding sectors, university units often need to operate in a large number of distinct disciplinary and sectoral domains, while enterprises mostly develop absorptive capacity in a fairly narrow sectoral setting (Kenney & Patten, 2009). At the organisational level, differences exist in the goals, interests and time horizons of university–industry R&D cooperation (Siegel et al., 2003). All of the above results in costs related to both accessing and integrating novel external knowledge (Balachandran & Hernandez, 2018). The costs of accessing and translating knowledge result not only from institutional factors but also from the tacit nature of knowledge, which, for the university, complicates the identification of possible areas for the application of knowledge and involves transaction costs for the firms (Fransman, 2008).

In terms of **the research gap**, a research-based, detailed understanding of how actors with different aims and operational logics interact internationally is lacking. Given the limited number of papers identified in my literature review (Article IV) as addressing international university–industry knowledge transfer, the question is what enables interaction among actors located simultaneously in different institutional contexts as well as in dissimilar organisational fields (a concept discussed in Section 1.2.1). It has been found that actors from different organisational fields can interact at the intersection of these fields; and, as new shared practices become institutionalised, the development of a new organisational field can occur (Furnari, 2016). Boundary work across organisational fields has addressed large-scale processes but has failed at times to capture a more fine-grained approach (Langley et al., 2019). Previous research has recognised the co-existence of shared network structure and common meaning system in an organisational field. However, most empirical studies have emphasised one component over the other and have neglected the temporal element, which enables the shared structural interactions to result in collective cognition (Coraiola et al., 2018). Compared to the structural features of the networks, the institutional characteristics of organisations and their geographical locations, which alter the characteristics of knowledge flows, have received limited attention (Owen-Smith & Powell, 2004). Additionally, analysing structural and institutional factors separately fails to address their combined influence (Balachandran & Hernandez, 2018).

Within this context, **my aim** is to explore how actors from multiple organisational fields interact internationally as well as the consequences of such interactions. International university–industry knowledge transfer is seen as involving cross-field intersections around shared issues between actors from different organisational fields. This means that I see the organisational fields as partly overlapping, thereby permitting organisations to maintain their main activities in their focal field and to engage in cooperation with actors from other fields. From the institutional analysis perspective, the institutions with their regulatory, normative and cognitive elements that structure the interactions are central to the functioning of the organisational field. However, the actors are both enabled and constrained by their geographical location and network structure in relation to institutional factors and by changes over time that bridge the other components of the field. Based on the above, I developed the following **research questions**:

RQ1: How do regulatory, normative and cognitive institutions foster international university–industry knowledge transfer?

RQ2: How is the relationship between geographical space and institutional factors constructed in international university–industry knowledge transfer?

RQ3: How are structural factors, including brokerage, related to institutional factors in international university–industry knowledge transfer?

RQ4: What role does time play in the interactions of actors from multiple fields in international university–industry knowledge transfer?

My thesis consists of four articles. Article I provides the means for answering RQ1 and RQ4; Article II contributes towards answering RQ2 and RQ4; Article III addresses RQ3 and RQ4; and Article IV is concerned with all the RQs (Figure 1). Three of the articles explore various channels of knowledge transfer: commercialisation (Article I), contract research (Article II) and collaborative research (Article III). Additionally, these articles address the sectoral divide in university–industry interactions, with Articles I and III differentiating between sectors with analytical and synthetic knowledge bases, and Article II focusing on the synthetic knowledge base.

Article I addresses the interplay between regulatory, normative and cognitive institutions by employing the case study approach to compare instances of international commercialisation in Estonia, India, Portugal and the UK. Article II explores the role of geographical proximity in relation to non-spatial proximity in the context of domestic and international contract research carried out in Estonia, also using the case study method. Article III takes a different approach from that of the previous papers, employing social network analysis to focus on EU-funded collaborative research projects in biotechnology and software in which organisations from the Baltic States have participated over a 20-year period. Article IV synthesises the studies on international university–industry knowledge transfer by means of a systematic literature review. The theoretical framework proposed in the article provides the basis for the other studies.

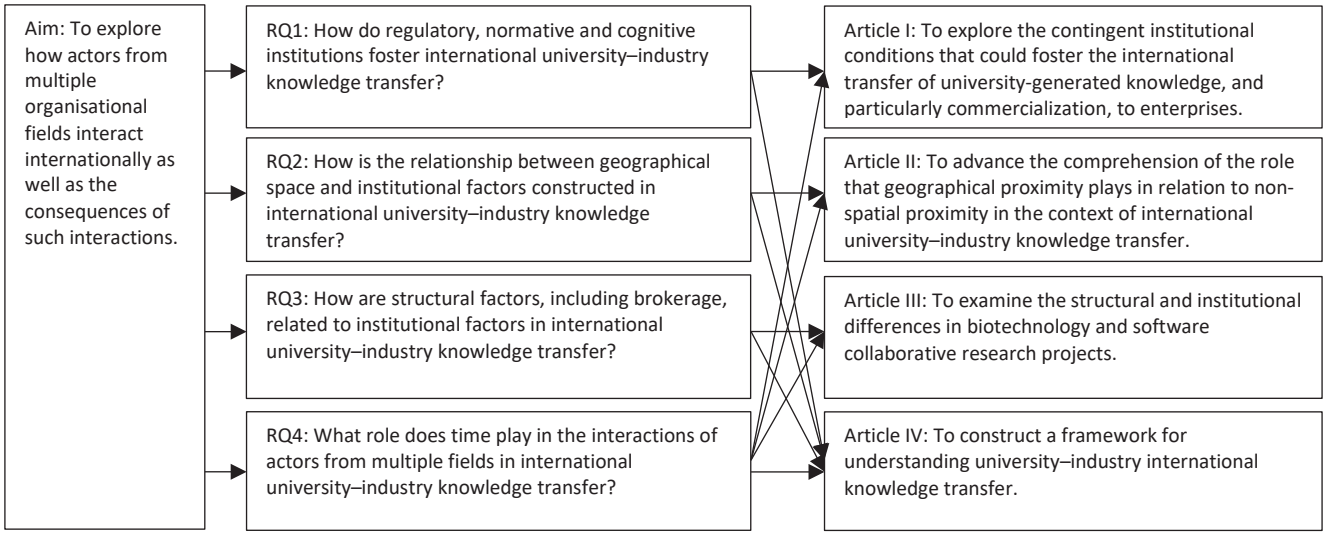

Figure 1. *Connections between the aim, the research questions and the articles*
Source: Compiled by the author

I **contributed theoretically** to international university–industry knowledge transfer by combining two perspectives: i) the influence of the organisational field on actors, and ii) relationships among the actors across fields and spatial distances.

Regarding the effect of institutional distance on the actors, I proposed a more detailed operationalisation of institutions consisting of the regulatory, normative, and cognitive elements at the individual, organisational and country levels (Article I). With this operationalisation I illustrated how the broad concept of organisational field consists of different elements of institutions at different levels not employed previously in studies of international knowledge transfer. I also showed that the long-term success or failure of international interactions depended on shared individual norms and cognitive frameworks as well as organisational knowledge bases (Article I). I found that different from domestic cooperation, international collaboration required similarities at both the individual and organisational levels (Article II).

As to the characteristics of relationships among the actors, I brought forth the differences between various types of organisations in their ability to connect actors and build networks internationally (Article III). I showed that the brokerage role of higher education and research organisations was more universal, while that of public bodies was sector-specific. As for the consequences of interactions, the comparative approach led to the finding that institutionalisation of international commercialisation was less apparent in smaller university contexts and in innovation-driven sectors (Article I). International contract and collaborative research, however, was more institutionalised even in the smaller universities (Article II, Article III).

I also **empirically contributed,** to studies of international university–industry knowledge transfer, the context of the emerging economy of Estonia (Article II) in comparison with economically more developed countries (Article I, Article III). Estonia represents an interesting context for comparative research with respect to its relatively recent strategic development of university–industry interactions and latecomer firms that need to invest in autonomous learning. What is specific about Estonia, is also the smallness of country and university contexts, reflected in the size of the enterprises and universities involved – allowing us insights into the effects of size on the knowledge transfer strategies used.

Regarding **managerial and practical implications**, I proposed the idea that knowledge transfer goes beyond market-based transactions led by the TTO (Article I). Successful transfer of knowledge required, especially in smaller university contexts, input from other actors as well, like academics and enterprises. This entails developing the entrepreneurship skills of academics as well as involving enterprises in the assessment of the commercialisation potential of technologies. Additionally, although much of the knowledge transfer takes place across spatial distances, I found it is facilitated in innovation-driven sectors by temporary geographical proximity (Article II). And, in a small country setting, domestic firms not experienced in R&D have different routes toward entering international knowledge networks, including cooperating first with local universities (Article III).

The thesis consists of a cover paper and four articles. In Chapter 1, I provide an overview of the theoretical framework, discuss the research phenomenon (international university–industry knowledge transfer) and relevant concepts employed for its study in the framework of neoinstitutional theory (organisational field, institutions, geographical space, network structure and time). Chapter 2 focuses on the research design, data collection and analysis methods as well as on evaluating the methodological choices. In Chapter 3, I outline the research results and discuss these in Chapter 4. Chapter 5 provides a conclusion where I present my theoretical, empirical and practical contributions, address limitations and propose areas for further research.

Abbreviations

EU	European Union
TTO	Technology transfer office
IP	Intellectual property
R&D	Research and development
NGO	Non-governmental organisation
MNC	Multinational corporation
KT	Knowledge transfer
TT	Technology transfer
FP	Framework Programme
H2020	Horizon 2020
ICT	Information and communication technology

1 Theoretical framework

1.1 International university–industry knowledge transfer

As the focal concept in this thesis, knowledge can be understood as 'a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information' (Davenport & Prusak, 1998, 5). Knowledge can be seen as justified true belief (Nonaka, 1994). It differs from data and information in that data comprise discrete facts about events without interpretation or suggestions for action, becoming information when meaning is applied (Davenport & Prusak, 1998). Information can be further distinguished from know-how in that information implies knowing its meaning, whereas know-how relates to knowing how to do something (Kogut & Zander, 1992).

Lam (2000) distinguished between the epistemological and ontological dimensions of knowledge. The epistemological divide is between explicit (codified) and tacit knowledge. The term *tacit knowledge* was introduced by Polanyi (1962) to refer to knowing something based on one's awareness. In this respect, tacit knowledge has a personal dimension and is related to a specific context, making it hard to formalise and communicate; explicit knowledge, on the other hand, is transferrable in formal and systematic language (Nonaka, 1994). Explicit knowledge can be acquired through formal study, while tacit knowledge is conveyed through practical experience (Lam, 2000). Distinguishing between these two types of knowledge in practice is problematic, as knowledge generation requires the combination of different types of knowledge (Nonaka & Takeuchi, 1995). The ontological distinction concerns individual and organisational knowledge. Although knowledge rests with individuals, it is also expressed by way of cooperation between members of a social community (a group, organisation or network) (Kogut & Zander, 1992).

This thesis looks at how organisations access knowledge from external sources. Knowledge transfer between universities and enterprises is understood as knowledge co-production involving bilateral/multilateral construction of knowledge, including also the tacit component, and takes place through interactions in networks and with benefits persisting over time (Rossi et al., 2017). There has been a shift away from a more linear understanding of university–industry technology transfer towards an evolutionary view of knowledge, whereby its exchange and utilization by the actors determines its value (Hayter et al., 2020). In this thesis, I use the term *knowledge transfer* to denote the exchange, (co)creation and application of knowledge.

University–industry knowledge transfer consists of academic and commercial engagement (Perkmann et al., 2013; Bozeman et al., 2013). The former mainly comprises contract research, collaborative research, consulting and informal networking, while the latter primarily involves commercialisation in the form of patenting, licensing and creating spin-offs. I explore in the thesis both academic and commercial engagement-related activities: contract research, collaborative research and commercialisation. Contract research is understood as R&D activities commissioned by industrial clients, whereas collaborative research is viewed as R&D arrangements between multiple organizations (Perkmann & Walsh, 2007). Commercialisation is defined as the transfer of a technological innovation for it to be utilized for producing marketable products (Kirchberger & Pohl, 2016). This divide between channels of knowledge transfer reflects the differential nature of cooperation from more knowledge-focused to more property-focused, as well as the degree of user involvement in knowledge generation.

I approach international university international university–industry knowledge transfer as a two-dimensional phenomenon (Table 1). On one hand, it can be understood as knowledge

transfer for the purpose of either academic engagement or commercialisation (Perkmann et al., 2013) between actors, i.e. organisations and individuals, of different types located in different countries. On the other hand, these international collaborations can be direct and indirect. Jin et al. (2011) distinguished between direct knowledge transfer between universities and enterprises in different countries, and indirect knowledge transfer between two universities mediated, for example, by local subsidiaries of MNCs in respective countries. As a result of these axial divisions, four types of international interactions emerge, which advances the understanding of international university–industry knowledge transfer addressed in a limited number of studies (22) that were identified in Article IV.

Table 1. *Typology of international university–industry knowledge transfer*

	Academic engagement	Commercialisation
Direct international linkage	Enterprise located internationally that participated in the production of the research outcome engages in its exploitation (Article II and III).	Enterprise located internationally develops a new relationship in order to access university generated and owned knowledge that is the result of curiosity-driven research (Article I).
Indirect international linkage	Enterprise located internationally that participated through a subsidiary, national university, national intermediary in the production and the exploitation of research outcomes (Article II).	Enterprise located internationally develops through a subsidiary, national university, national intermediary a new relationship in order to access university generated and owned knowledge that is the result of curiosity-driven research.

Source: Article I (Kalantaridis et al., 2017).

Direct international linkage in academic engagement implies that the user-enterprise participates in contract research or collaborative research directly with a foreign university and engages in its exploitation (e.g. in Article II and III). Indirect international linkage in academic engagement refers to a situation in which the user-enterprise participates in international contract research or collaborative research through a national subsidiary, local university or other intermediary body (e.g. in Article II). Direct international linkage in commercialisation means that the user-enterprise develops a direct new relationship with a foreign university to exploit knowledge generated at the university without the prior involvement of the enterprise (e.g. in Article I). Indirect international linkage in commercialisation refers to a situation in which the user-enterprise's involvement occurs through a third actor to exploit knowledge generated in a foreign university without the prior involvement of the enterprise.

1.2 Neoinstitutional theory in the context of international university–industry knowledge transfer

Neoinstitutional theory in sociology and organisational studies (DiMaggio, 1998; Nielsen, 2001) provides the theoretical basis for studying international university–industry linkages. Neoinstitutional theory examines how the institutional environment shapes, mediates and channels social choices (Wooten & Hoffman, 2017). More specifically, neoinstitutional theory studies how institutional arrangements (schemas, rules, norms and routines) that guide social behaviour are created, diffused, adopted, developed and changed, as well as how they disappear over time (Scott, 2005). According to the systematic literature review I undertook

in Article IV, focusing on international university–industry knowledge transfer, neoinstitutional theory has been applied in previous university–industry studies. Malik (2013) found that institutional distance between actors matters in international cooperation. More specifically, religious, social and educational distance between the actors influences the effectiveness of international university–industry interactions positively, whereas the level of industrial development exerts a negative impact, and political distance has no effect. Additionally, geographical proximity plays a different role depending on the institutional backgrounds of actors. Ponds et al. (2007) stated that organisations with the same organisational form tend to collaborate over geographical distances more so than organisations with different institutional backgrounds.

Compared to alternative theoretical approaches, neoinstitutional theory is suitable for studying international university–industry knowledge transfer as it adopts the social constructivist approach (Nielsen, 2001). Knowledge, which is the focal concept in knowledge transfer, is also seen as embedded in social activities and practices (Young, 2008) and created by the interactions between actors rather than being discovered (Lincoln & Guba, 2013). Alternative approaches, like transaction cost theory, property rights economics and principal-agent theory, employ the concept of rationality and adhere to a more positivist tradition in economics (Rendtorff, 2016). Neoinstitutional theory and network theory can be seen as complementary approaches. The difference is that while the theory of the field sees the types of capital and symbolic power of actors as the basis for their position in a social space, network theory is more individualistic in its approach, looking at the number of ties possessed by actors (Kirschbaum, 2012). Social network analysis is needed, nevertheless, for disclosing the processes in which interpersonal relations restructure a field (Nooy, 2003).

However, the use of neoinstitutional theory is not without limitations. Its rapid development has resulted in the theory becoming increasingly vague, with unclear boundaries regarding institutions, institutional logic and institutional work (Alvesson & Spicer, 2019). The challenge in neoinstitutional theory has been to address both change and stability, as well as agency and structure (Bouilloud et al., 2020). While the changing focus, also called organisational institutionalism, has made it possible to advance research agendas and account for institutional variation and change, there is still a need to define institutions and the essence of institutional analysis (Ocasio & Gai, 2020).

1.2.1 Organisational field and cross-field intersections

Central to neoinstitutional theory is the concept of an organisational field that penetrates the organisations and creates the lenses through which actors view the world (DiMaggio & Powell, 1991). Organisational field can be narrowly defined as 'those organisations that, in aggregate, constitute a recognised area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organisations that produce similar services or products' (DiMaggio & Powell, 1983, 1991, 64). According to a wider view, it means 'a community of organizations that partakes of a common meaning system and whose participants interact more frequently and fatefully with one another than with actors outside of the field' (Scott, 1994, 207−208; 2008, 86). The concept of organisational field is related to that of Bourdieu's field (1971; 1984) in sociology, which focuses on how networks of social relations structure actions in different arenas, including political, economic and cultural (Scott, 2008). Early approaches to organisational field emphasised the coercive, mimetic and normative forces that produce homogeneity (organisational isomorphism), as organisations are subject to common formal and informal pressures, cultural expectations, the desire to be legitimate, professional and successful (DiMaggio & Powell, 1983, 1991). Later approaches introduced the notions of variation, change, conflict, strategic action and

variety, seeing the organisational field as dynamic and contested by powerful actors (Wooten & Hoffman, 2017; Zietsma et al., 2017).

I focus in the thesis on the interactions that take place at the intersections of organisational fields and see the organisational fields as overlapping and embedded in each other. International university–industry knowledge transfer involves actors whose main activities belong to different organisational fields and it necessitates actions outside their core operations. Universities are characterised by ambiguous technologies and hard-to-define goals in education and research, while enterprises produce more easily measured outputs with business venturing (Morphew & Huisman, 2002). Cross-field intersections between these actors bring together certain activities and leave apart others, allowing interactions across physical, social, temporal or symbolic spaces (Langley et al., 2019). Being embedded in distinct yet overlapping fields, means that the actors address joint issues according to their distinct institutional logics (Evans & Kay, 2008). This means differences in values, beliefs and normative expectations by which the actors make sense of, evaluate and organise their activities (Haveman & Gualtieri, 2017). The fields that are formed around shared issues encompass these multiple and conflicting logics of actors in addition to the overall changing nature of the field (Zietsma et al., 2017). Based on this, I propose the actors are influenced in the field of international university–industry knowledge transfer by the prevailing institutions, geographical location and network structure that change over time.

1.2.2 Institutions in the organisational field

Various institutions support the actors by providing legitimacy and by facilitating interactions, while also establishing boundaries to the interactions and constraining actors (Scott, 1995, 2008). The difficulty in operationalising the concept is related to there being multiple and conflicting definitions of institutions (Alvesson & Spicer, 2019). Institutions can broadly be understood as informal constraints and formal rules, with the former including sanctions, taboos, customs, traditions and codes of conduct, and the latter comprising constitutions, laws and property rights (North, 1991). More specifically, these are social structures composed of regulative, normative and cultural-cognitive elements that confer stability and meaning to social life together with associated activities and resources (Scott, 1995, 2008). The thesis employs a distinction between regulatory, normative and cognitive institutions as it allows to analyse the broad concept of organisational field through different elements of institutions.

Regulative institutions involve a coercive mechanism with the capacity to establish rules, surveillance mechanisms and sanctions to influence behaviour, and these institutions stem mainly from governmental legislation, industrial agreements and standards (Scott, 2003, 2008; Bruton et al., 2010). Regulative frameworks denote, at the country level, the characteristics of intellectual property regimes, mainly institutional or individual ownership (Geuna & Rossi, 2011). At the organisational level, these involve the centrality of technology transfer offices in the intermediation between universities and enterprises (Phan & Siegel, 2006), in addition to the rules and mechanisms regulating disclosure and academic entrepreneurship (Grimaldi et al., 2011). As a major regulatory change, the adoption of the Bayh-Dole Act in 1980 in the US, and its counterparts in other countries, allocated universities the ownership rights of patents arising from state-funded research grants (Grimaldi et al., 2011).

Normative institutions are binding expectations that introduce a prescriptive, evaluative and obligatory dimension into social life, and they are composed of values and norms that establish consciously followed ground rules (Scott, 2003, 2008; Powell, 2007; Bruton et al., 2010). At the individual level, there are descriptive and injunctive norms; whereas the former describes the prevalence of a certain behaviour and encourages its adoption, the latter is

related to the evaluation attributed to a certain behaviour by others (Cialdini et al., 1990). The interactions across the organisational field's boundaries influence the identity of individuals, as academics tend to fulfil a dual role in commercialisation activities, one that consists of an academic self and a secondary commercial persona (Jain et al., 2009). However, this dual role can foster conflict, as the adoption of norms associated with entrepreneurial behaviour must be reconciled with traditional scientific norms (Perkmann et al., 2013). A similar duality of norms may occur in enterprises, where, according to the university–industry interaction, a process of enterprise scientification may occur, i.e. the adoption of open science norms (Bjerregaard, 2010). For example, start-ups in science-driven sectors are subject to both academic and market logics (Battilana et al., 2017).

Cultural-cognitive institutions are mimetic, meaning the creation of shared conceptions that constitute the nature of social reality and the frames through which meaning is made; e.g. culture and language (Scott, 2003; Powell, 2007; Bruton et al., 2010). At the individual level, these cultural-cognitive institutions are the language used by participants and their cognitive frameworks (educational background) (Malik, 2013); at the organisational level, this means shared knowledge bases (patents in similar areas) (Lane & Lubatkin, 1998). In terms of institutional differences predicting alliances between organisations, legal and cultural differences between countries, power distance, uncertainty and long-term orientation have all been found to generate a positive effect (Malik & Yun, 2017). Regarding collaborative research projects, which tend to be more long term and research-oriented, Bjerregaard (2010) has shown that shared cultural space contributes to the institutional convergence and blurring of institutional logics between SMEs and public university departments.

1.2.3 Geographical space in the organisational field

Neoinstitutionalism in organisational analysis shares with economic geography the idea that the degree of sharing a common ideational space is associated with a corresponding proximity of geographical space (Glückler et al., 2018). Earlier approaches to organisational field focused more on co-location; while in later studies, organisations were increasingly seen as affected by and responsive to forces beyond their local environment (Scott, 2008). The idea that non-spatial forms of proximity can be differentiated from spatial proximity originated from the French School of Proximity Dynamics in the 1990s (Boschma, 2005). However, the critique of the vast body of literature that has made use of the proximities concept has highlighted that different numbers of proximity dimensions have been used, with conceptual overlaps between them (Knoben & Oerlemans, 2006). Employing different levels of analysis (aggregate or individual) have also led to different results as research outcomes are dependent upon operationalisations (Hansen, 2015). The thesis makes use of five proximity dimensions based on Boschma (2005), including geographical, cognitive, organisational, social and institutional proximity as it allows distinguishing between institutional and other forms of proximities.

Geographical proximity is understood as the spatial or physical distance between actors (Boschma, 2005). It denotes, at the organisational level, the spatial distance between the actors (Steinmo & Rasmussen, 2016). Geographical proximity has been operationalised in previous studies as degrees of proximity, including, for example, regional, national and international dimensions (Hansen, 2015; Petruzzelli, 2008; Steinmo & Rasmussen, 2016), or as the distance in kilometres between the actors (Broekel & Boschma, 2012; Hoekman et al., 2009). Geographical proximity is helpful in knowledge transfer as it contributes to the transfer of tacit knowledge (Knoben & Oerlemans, 2006). It has been found that higher-performing research groups are more interested in cooperating with distant firms (Garcia et al., 2014). Also, firms possessing higher levels of absorptive capacity tend to create

more spatially distant links with universities (de Fuentes & Dutrénit, 2016). While geographical proximity is helpful in terms of local knowledge spill overs (Grillitsch & Nilsson, 2015), it is not a necessary condition for learning and interactive innovation (Boschma, 2005). Other proximities might, depending on the context, be even more important (Balland et al., 2015).

In addition to spatial forms of proximity, there are also non-spatial proximities. First, cognitive proximity is understood as a shared expertise and knowledge base between actors (Boschma, 2005). It signifies, at the organisational level, comparable R&D experience and technological similarities (Steinmo & Rasmussen, 2016); and, at the individual level, the shared educational background of individuals (Hansen, 2015). It has also been used in studies as a similarity of technology/patent class and the economic activities of actors (Broekel & Boschma, 2012; Petruzzelli, 2008). Higher absorptive capacity, meaning the firm's ability to recognise the value of new, external information, to assimilate it, and to apply it to commercial ends (Cohen & Levinthal, 1990), has been found to increase the cognitive proximity between partners, even if they are geographically distant (De Jong & Freel, 2010). Too much cognitive proximity, however, could be harmful for novelty and learning (Nooteboom et al., 2007; Natalicchio et al., 2018), understood as the proximity paradox (Broekel & Boschma, 2012).

Second, organisational proximity characterises the extent of shared institutional arrangements resulting in inter-dependence and control between the actors (Boschma, 2005). It can be seen at the organisational level as actors belonging to the same legal entity, like networks, alliances, clusters or consortia (Hansen, 2015; Balland, 2012; Petruzzelli, 2008). Third, social proximity consists of trust-based relations between partners (Boschma, 2005). It consists, at the organisational level, of organisations which have partners in common (Balland, 2012); and, at the individual level, of persons who possess previous contacts and mutual acquaintances (Hansen, 2015; Broekel & Boschma, 2012; Steinmo & Rasmussen, 2016). Networks based on previous interactions have been found to be characterised more by strong, trusting relationships for accessing knowledge, while newer connections tend to be weaker and more formalised (Sousa & Fontes, 2014). Fourth, institutional proximity consists of formal and informal institutions (Boschma, 2005). Formal constraints involve constitutions, laws and property rights, while informal constraints include sanctions, taboos, customs, traditions and codes of conduct (North, 1991). This means, at the organisational level, a similar institutional setting in terms of co-location that influences legislation and national culture (Hoekman et al., 2009); and, at the individual level, shared norms and values (Slavtchev, 2013). It has also been operationalised as similarities in organisational types (Ponds et al., 2007; Balland, 2012).

1.2.4 Network structure of the organisational field

Central to the organisational field is a network of actors connected by a shared structure and system of meanings. An organisational field is a relational system, a network, and organisations operating in the field inhabit distinctive positions, with diverse threats and opportunities (Scott, 2008). The brokering between otherwise unconnected actors, i.e. connecting 'structural holes' or social spaces in the network, has been found to increase the actors' social capital, allowing access to unseen solutions (Nooteboom, 2003; Burt, 2004). It involves recombining and exploiting knowledge drawn from various sources (Hargadon & Sutton, 1997), the transfer and conversion of knowledge (Chen et al., 2015), and increasing trust between the actors (Kauffeld-Monz & Fritsch, 2013). Furthermore, being in a position in the network that bridges different organisational fields, decreases the institutional embeddedness of the actor in their own field, highlights tensions between multiple fields, and contributes to the awareness of alternatives (Greenwood & Suddaby, 2006). Studies

have found research organisations to be more important for international knowledge transfer, as they are connected to more actors and are able to absorb more knowledge (Chen et al., 2015; Kauffeld-Monz & Fritsch, 2013). There are also a variety of intermediary actors operating in the periphery of the field that endeavour to bridge the different institutional logics of academia and industry (Villani et al., 2017). These include technology transfer units, consultants, technology brokers, innovation service providers, and public and private agencies supporting technology transfer (Battistella et al., 2016).

The thesis distinguishes between sectoral networks as these are characterised by different knowledge-sharing patterns, central actors and geographical scope. Differentiation is made between analytic and synthetic knowledge base (Asheim & Gertler, 2005; Asheim & Coenen, 2005) with biotechnology being representative of the former and software of the latter. The concept of a differentiated knowledge base was first used to analyse such knowledge-sharing patterns, while later studies have included the interconnections with proximities and related variety (Boschma, 2018). The critique against over-simplification of the concept has led to the combinatorial approach, which acknowledges that several knowledge bases can exist simultaneously (Davids & Frenken, 2018) and that the knowledge base can transform over time (Manniche et al., 2017).

Networks in science-driven sectors characterised by an analytical knowledge base have been found to include R&D organisations as central actors (Asheim & Gertler, 2005; Asheim & Coenen, 2005) and to remain weakly regionally embedded (Liu et al., 2013). Codified knowledge in the form of patents employed to protect intellectual property (Wal & Boschma, 2009) is likely to increase the willingness of firms to collaborate at a distance with globally dispersed partners (Herstad et al., 2014). In the case of innovation-driven sectors with a synthetic knowledge base, emphasis is placed more on localised, path-dependent, inter-firm learning processes (Asheim, 2007), which are concentrated around focal firms (Salavisa et al., 2012). In the case of the synthetic knowledge base, the more specific know-how, crafts and practical skills attributable to the dominance of tacit knowledge are harder to exchange over physical distances (Asheim et al., 2007). Thus, networks in industries based on analytical knowledge have been found to emerge around universities and to remain weakly embedded in the host region; meanwhile, firms relying on synthetic knowledge tend to develop close linkages at the regional level with universities missing from the network or present with other central firms (Liu et al., 2013; Salavisa et al., 2012).

1.2.5 Time in the organisational field

In addition to shared meanings, geographical space and network structure, there is also the temporal element of developing a shared understanding over time (Coraiola et al., 2018). A distinction can be made between cyclical and linear time, with the former emphasising organisational planning and relying on past events to predict future events, and the latter stressing the choice of a new path and the acting out of the future (e Cunha, 2004; Ellwood et al., 2017). Path dependency guides the actions of actors at the expense of pursuing new avenues (Ellwood et al., 2017). Previous studies have emphasised the importance of the institutional environment from which actors originate, as national barriers operate within an organisational system and are highly path-dependent (Hwang, 2010). For universities, path dependency and organisational culture have been found to constrain knowledge transfer and the capacity to interact with external actors (McAdam et al., 2017). The cumulative nature of absorptive capacity also restricts the activities of firms to specific domains and requires a deliberate effort to create absorptive capacity when knowledge not fully related to their regular activities is acquired and used (Cohen & Levinthal, 1990).

Time has been found to enable a shared network structure culminating in collective cognition (Coraiola et al., 2018). At the start of university–industry cooperation, social,

organisational and cognitive proximity can act as substitutes for geographical proximity; whereas social and geographical, as well as institutional and geographical, proximity have been found to co-exist (Hansen, 2015). Cognitive proximity may increase over time for geographically and socially close engineering-based firms and research organisations (Steinmo & Rasmussen, 2016). Social proximity can also develop over time as trust-based relations emerge, decreasing the possibilities for opportunistic behaviour (Boschma, 2005), especially for cognitively and organisationally proximate science-based firms and research organisations (Steinmo & Rasmussen, 2016). Firms experienced in working with universities and research organisations have been found to start collaborations based on cognitive social capital, which is reinforced by the development of relational social capital over time; while less experienced firms establish their interactions with the university on relational social capital, and cognitive social capital increases over time (Steinmo & Rasmussen, 2018). There is a need, however, to understand better the interaction and connections between geographical space and institutional factors (Hansen, 2015) and the dynamic aspects of networked collaborations over time (Steinmo & Rasmussen, 2016).

Interacting across organisational fields can lead to the emergence of new temporary or permanent organisational fields. The temporary nature of organisational fields implies that these fields come alive only when the actors perceive the need to interact (Wooten & Hoffman, 2017). The emergence of a more permanent new field requires that successful interaction rituals emerge as well, in addition to catalysts to sustain interactions and contribute to the construction of shared meanings (Furnari, 2014). The organisational field's boundaries become formalised and managed by the boundary organisations (Zietsma et al., 2017). The new shared practices become institutionalised with the emergence of rule-like organised patterns of action and formalisation (Zucker, 1987, 2012). Field formation has been found to result from disruptive events in the form of exogenous shocks (Wooten & Hoffman, 2017). Also, mutual dependence between the fields has been found to contribute to the likelihood of actors creating new shared institutions to regulate their relations (Furnari, 2016). In university–industry interactions, the adoption of the Bayh-Dole Act and its counterparts decreased public funding, and increased the accountability of universities to multiple stakeholders that has contributed to the forging of interactions with the industry. For the knowledge transfer process to become institutionalised, the emergence of new legitimacies, regulations and resources, which the actors can reinterpret and reconstruct, is required (Pinto, 2017). The institutionalisation of rules and practices is, in turn, related to the development of shared beliefs (Baldini et al., 2014).

1.3 Theoretical framework of the study

In this sub-section I construct a theoretical framework based on influencing factors of international university–industry knowledge transfer discussed previously. The organisational field is the intermediate unit between actors at the microlevel, and societal and transocietal institutions residing at the macrolevel (Scott, 2008). The interaction between different levels involves top-down processes comprising of diffusion and imposition of institutions to provide the overall operating environment, and constrain and empower lower level actors (Figure 2). Bottom-up processes consist of invention and negotiation enabling lower level actors to reproduce and change their contexts.

I acknowledge that the organisational field is a structured phenomenon consisting of multiple reciprocal components (Coraiola et al., 2018). First, regulatory, normative and cognitive institutions provide boundaries to the interactions and inhibit actors from selecting alternative modes of action. Second, the actors are connected not only by a shared meaning system, but by geographical space (Glückler et al., 2018). The notion of space has changed

from co-location to organisations being increasingly affected by and responsive to forces beyond their local environment (Scott, 2008). Third, an organisational field is a relational system, a network (Scott, 2008). In the network structure, organisations and individuals occupy various hierarchical positions. The socially skilled actors can act as brokers connecting 'structural holes' or social spaces in the network (Burt, 2004). Fourth, time is seen as a connecting mechanism that bridges the cognitive and structural elements of organisational fields and permits collective cognition to emerge (Coraiola et al., 2018).

In the context of international university–industry knowledge transfer, I propose that the actors interact at the intersections of organisational fields. This collaboration is anchored in a specific issue, which is either academic engagement or knowledge-focused, i.e. contract research and collaborative research, or property-focused, i.e. commercialisation (Perkmann et al., 2013; Bozeman et al., 2013). Additionally, actors' interactions can be direct or indirect, involving direct relationships across national boundaries between universities and foreign enterprises or the user-enterprise's indirect involvement through a third party (local subsidiary, local university, other intermediary) (Jin et al., 2011).

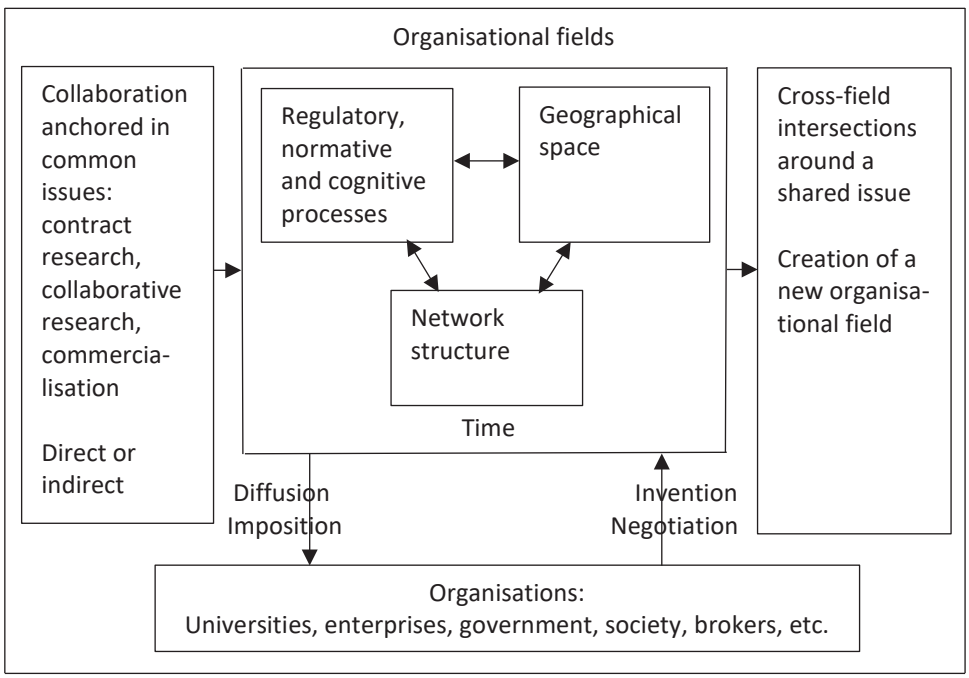

Figure 2. *The process of international university–industry knowledge transfer from the organisational field perspective.*

Source: composed by the author based on Scott, 2008; Matten & Moon, 2008; Jamali & Neville, 2011.

From the organisational field perspective, knowledge transfer activities can take place as cross-field intersections characterised by formalised arrangements aimed at the governance of resources and the management of shared issues (Zietsma et al., 2017). Mutual dependence exists between organisational fields and the activities of actors, as organisational fields provide rules and resources for cooperation, while collaboration creates ongoing processes of structuration that maintain the organisational fields (Phillips et al., 2000). Interactions can also result in the formation of a new issue field with newly established institutions and institutionalised processes (Furnari, 2016).

2 Methodology

2.1 Research design

The research philosophy that led to the methodological choices made in this research stems from the general idea of social constructivism. It expresses my understanding of reality in that, based on experience, meanings are created through interaction, and thereby inform actions. Social constructivism stipulates at the ontological level that multiple realities are constructed through people's experiences and via interactions with others, and that, at the epistemological level, reality is co-constructed between the researcher and the researched (Creswell, 2013). Constructivism posits that entities are matters of definition and convention, existing in the minds of the persons contemplating them, and that the relationship between the knower and the knowable depends on persons and contexts (Lincoln & Guba, 2013). Knowledge is seen as embedded in social activities and practices (Young, 2008). As knowledge is the result of social interaction, the criterion against which knowledge is judged is consensus between individuals (Adams, 2006). Thus, knowledge is created rather than discovered and therefore does not exist beyond the time and space in which it is generated (Lincoln & Guba, 2013).

I employed in the thesis abductive approach to theory development, which allowed me to move between theory and data in order to develop conclusions based on available evidence (Saunders et al., 2016). As to the methodological choices, I used the triangulation of methods and data to enhance understanding of the phenomenon under study to increase the validity of the overall findings (Stoker, 2011). I combined qualitative and quantitative approaches that permitted the examination of different aspects of university–industry knowledge transfer (Bryman & Bell, 2003) via a series of consecutive studies (Leech & Onwuegbuzie, 2009). This meant, I looked qualitatively at international commercialisation and contract research (Articles I and II) and quantitatively at international collaborative research (Article III).

I used, furthermore, various research strategies and time horizons. First, I employed case study research in Articles I and II. This strategy permitted a robust and compelling exploration of a contemporary phenomenon in its real-life context (Yin, 2009, 2018), involving detailed, in-depth data collection from multiple sources (Creswell, 2013). I found it suitable for analysing knowledge transfer in that it allowed the placement of research in a certain context by the selection of relevant sectors, institutions, countries, etc. (Cunningham et al., 2017). I collected the data cross-sectionally at a specific point in time. Second, I used social network analysis in Article III. This strategy focused on relational data and analysed how actors and groups were linked via contacts, ties and connections (Scott, 2013). I decided that collaborative research projects were amenable to social network analysis, as they involved multiple partners representing different organisation types, countries, disciplines and/or sectors. I collected the data longitudinally over a 21 year period and compared the different time periods. Third, I employed a systematic literature review in Article IV and followed the steps outlined by Tranfield et al. (2003), which consisted of planning, conducting, reporting and disseminating. This strategy facilitated answers to a clearly formulated question by finding, describing and evaluating evidence from all published sources pertaining to that question within a defined set of boundaries (Eriksson, 2013; Davies, 2000).

2.2 Data collection and analysis

We designed Article I as a multiple-case study of eight cases of international commercialisation from Estonia, India, Portugal and the UK (Table 2). These national contexts were selected to represent diversity on scales suggested by Audretsch et al. (2014) in terms of institutional development and knowledge-generating capabilities. Universities with a technological

orientation and relatively strong knowledge-generating capabilities were chosen for the study. Differentiation was made between science-driven and innovation-driven sectors. 47 semi-structured in-depth interviews (with five target groups: senior university managers, technology transfer specialists, academics, entrepreneurs and government officials) were conducted. I undertook 10 interviews in Estonia by using purposeful sampling, comprising criterion sampling and snowball sampling (Patton, 2002). The interviews were recorded and transcribed. The interview schedules were developed based on the literature review and consisted of knowledge production, knowledge transfer, actors and relationships, governance and management of knowledge transfer. The study also utilised document analysis to access multiple sources of information (e.g. national R&D policy documents and analysis, university regulations, university R&D reports, webpages, press releases, and databases). First, we used directed content analysis to code the interview data in terms of key themes identified in the literature (Hsieh & Shannon, 2005). The themes included regulatory, normative and cognitive institutions at various levels. Second, we searched for patterns across cases, and merged the emerging themes into overarching categories (Miles et al., 2014).

Table 2. *Overview of research designs, samples, data collection and analysis methods*

	Article I	Article II	Article III	Article IV
Research context	Multiple-case study of eight instances of commercialization from Estonia, India, Portugal and UK	Multiple-case study of nine instances of contract research at Tallinn University of Technology	Social network analysis of EU research projects 1995-2016 with actors from the Baltic States	Systematic literature review
Data collection methods	Document analysis and semi-structured in-depth interviews	Document analysis and semi-structured in-depth interviews	Document analysis of project descriptions and partners from the Cordis database	Document analysis
Sample	47 interviews in two sectors (analytic and synthetic) with five stakeholder groups in four countries; eight with senior university managers, 16 with academics, nine with technology transfer specialists, eight with entre-preneurs, six with government officials; 10 in Estonia, 12 in India, 13 in Portugal, 12 in UK	20 interviews in one sector (synthetic) with five stakeholder groups; two with senior university managers, two with technology transfer specialists, eight with academics, four with entre-preneurs, four with government officials	407 projects in two sectors (analytic and synthetic), 3,441 organizations (1995-2016)	22 research articles from Scopus and Web of Science
Data analysis methods	Qualitative content analysis, thematic coding, finding overarching themes	Qualitative content analysis, thematic coding, finding overarching themes	Social network analysis, Kruskal-Wallis H test, post-hoc Tamhane T2 test	Qualitative content analysis, thematic coding, finding overarching themes, bibliographic network analysis

Source: Compiled by the author

In Article II, I undertook a multiple-case study of nine instances of contract research in the innovation-driven sector at Tallinn University of Technology, Estonia. The cases were selected to include enterprises of different sizes as well as instances of success and failure. I sought the information from five groups of interviewees, 20 in total, with whom I performed semi-structured, in-depth interviews. Purposeful sampling by means of criterion sampling was used to locate international and domestic cases of contract research and interviewees who met the aforementioned criteria, while snowball sampling was used to identify additional persons of interest (Patton, 2002). The interviews were recorded and transcribed. The same interview schedules were utilised as in Article I. To complement interview data, document analysis was undertaken, which included reading a country's and university's regulations, a university's annual R&D reports, financial documents, webpages, press releases, and databases. I organised the interview data first into a partially ordered descriptive matrix, after which a variable-by-variable matrix to explain relationships was developed (Miles et al., 2014). The partially ordered descriptive matrix included illustrations from the cases of cognitive, organisational, social and institutional proximity. The variable-by-variable matrix demonstrated the division of cases according to the complementarity and substitution mechanism between spatial and non-spatial forms of proximity.

We examined in Article III, by means of social network analysis, the composition and structure of EU research projects, in which organisations from the Baltic States participated for more than 20 years. The data originated from documentary sources, i.e. from the EU Cordis database, and covered the science-driven and innovation-driven sectors (biotechnology and software). These sectors were included in the analysis as they represent different knowledge bases (analytic and synthetic) and thus lead to differences in the core ideas of innovation as well as in institutional and structural network characteristics (Salavisa et al., 2012). Our sample comprised 407 projects and 3,441 organisations. Since relational data consist of connected pairs of interacting agents (Scott, 2013), pair-wise matrices were used for data analysis to indicate the existence or absence of a link between two organisations to calculate network measures (in UCINET) and visualise the networks (in Netdraw). First, we calculated network metrics to characterise the sectoral knowledge networks. Second, we undertook between-group comparisons by means of a nonparametric Kruskal-Wallis H test and post-hoc Tamhane T2 test (in SPSS) to examine the differences in brokerage roles, i.e. coordinator, gatekeeper, consultant, liaison (dependent variables) between organisation types (independent variable).

In Article IV the relevant studies published on international university–industry knowledge transfer from 1970 to 2015 were identified for the systematic literature review, using a variety of keywords and their combinations from Scopus and Web of Science. After several rounds of reviews undertaken independently by both authors, we included 22 papers in the analysis that met the inclusion criteria. The articles selected for analysis were read and synthesised by compiling the main information for each study into data-extraction tables (author and publication year, research questions, source of data, methodology, variables used and findings). We analysed the data using qualitative content analysis to search for the main themes identified in the literature: channels, motivations, activities and outcomes, and influencing factors that characterise international university–industry knowledge transfer and its relationship with the internationalisation of R&D, innovation systems and higher education. We also used the bibliographic network analysis of author keywords (in VOSviewer) to graphically represent bibliometric maps using keywords from articles based on co-occurrence data (van Eck & Waltman, 2010).

2.3 Evaluation of methodological choices

In Articles I and II, I addressed reliability by pre-testing the interview schedule. Additionally, at the start of the analysis, we analysed the interview data independently with the first author, and discussed the consistency of the findings and the applicability of the analytical framework. The validity of the study was increased by using different data sources. The combination of interviewee groups and interview data with document analysis lent support to the subjective accounts of interviewees and situated the findings of the interviews in a wider context. After the analysis was complete, I asked one of the Estonian interviewees to read the text to validate the research findings. In terms of external validity, the generalisability of the study results was limited to the same type of university context (technology-focused, leading research and knowledge transfer) and channel of knowledge transfer (commercialisation or contract research) that were included into the studies. Another limitation of the studies was that they addressed knowledge transfer from the university perspective, as the majority of interviewees worked in academia. Also, only a limited number of cases in which cooperation failed with regard to institutional factors were identified.

In Article III, the use of different data sources might have yielded different results, as the structures of the networks studied were greatly determined by the rules and requirements of EU funding schemes. In addition, using secondary data (project descriptions and lists of partners) rather than primary data (interviews or surveys with project participants) restricted our scope of data analysis and led to simplifications (e.g. a mutual link was assumed to exist between project participants, while in reality there might have been more intensely related sub-groups within a project). The division of projects into time periods based on framework programmes produced networks of different sizes. This influenced some of the networks' characteristics, like density. It was more difficult for the actors to be connected with a larger proportion of other actors in larger networks. The use of CORDIS data limited the number of variables in this study as well. As the organisation types and locations were recorded in the database, these were also included in the study.

In Article IV, to reduce selection bias and increase reliability, both I and my co-author read the papers and decided independently whether the papers met the pre-determined inclusion criteria into the study. Differences were discussed until a joint decision could be made. Data extraction forms that contained the main information about the papers were used to document the decision-making process and provide the basis for further analysis. The limitation of the study was that the analysis of previous research was restricted to English-language articles in Scopus and Web of Science, thereby only partly covering the extant research published on the topic, leaving out work published in other languages as well as other types of publications.

I find the methodological choices allowed for the in-depth exploration of the phenomenon under study and increased the validity of the overall findings, corresponding to the aim of the study and facilitating the answering of the research questions.

3 Results

In this section, I explore the interaction between the components of the organisational field (institutions, geographical space, and structure with time cross-cutting across the other three components) as both enabling and constraining factors of international university–industry knowledge transfer. I provide an overview of the empirical results from the Articles I–III.

3.1 The role of institutional factors in international university–industry knowledge transfer

In Article I, I explore the role of regulatory, normative and cognitive institutions in the international commercialisation of university-generated knowledge, thereby contributing to addressing RQ1 and, in terms of the discussion on the path dependency of interactions, RQ4. I drew the theoretical framework of the study on neoinstitutional theory, which emphasises the constraints imposed on the interactions of actors operating in different organisational fields (Furnari, 2016). In the framework, I distinguished between regulatory, normative and cognitive institutions that enable, structure and limit social life (Scott, 1995, 2008).

Eight cases of international commercialisation between university and foreign enterprises in science- and innovation-driven sectors originating from universities located in Estonia, India, Portugal and the UK were compared. In terms of the regulatory factors, the interview and document analysis results show that a state-level legislative framework was required for the successful international commercialisation of university-generated knowledge. This framework prevented fraud and outlined the rights and obligations of the actors. The effective protection of the university-generated IP was important, especially among cases in science-driven sectoral systems and for environments from which enterprises that used the technology originated. At the organisational level, there was a differential advancement of rules at both universities and enterprises. Universities in the UK and India had established distinct, wholly-owned university subsidiaries to promote international commercialisation. However, only in the UK was international commercialisation a part of strategic intent. In Estonia and Portugal, the TTOs were part of the university structure, but they focused more on types of knowledge transfer other than international commercialisation. The small patent portfolio and the absence of patent families meant that international commercialisation was less commonplace and was led mostly by the academic inventor. For enterprises, the organisational rules were well developed in non-practising entities and in MNCs, as these operated globally. Conversely, they were less-developed for small academic spin-offs.

Regarding normative factors, new international interactions in commercialisation were developed between participants who were influenced by shared normative institutions. These comprised shared injunctive norms (perceived social pressure) and descriptive norms (perceived prevalence of behaviour). They were highly path-dependent as a result of organisational decisions, investments and the overall institutional logics that had evolved over time. Particularly important were norms associated with ‘science commons’ (e.g. openness, community, mutual criticism and fair allocation of credit), which were apparent in all but two cases. These norms were facilitated by individuals who had held positions in both academia and enterprises. On the other hand, the misalignment of scientific and commercial norms led to a break-down of interactions in one of the cases. Regarding shared normative descriptive institutions, individuals operated in environments in which commercialisation activities were commonplace. Academic inventors at universities and users in enterprises worked in departments in which patenting activity was high.

As for cognitive factors, these consisted of common a linguistic space, a common organisational knowledge base (patents in similar areas) and shared individual cognitive frameworks (educational backgrounds). Similarly to norms, also cognitive elements were part-dependant as organisational choices about developing absorptive capacity and individual decisions regarding education and work experience had accumulated through time. The results indicated, on the one hand, that a common linguistic space was an essential precondition for the initiation of cooperation. Shared educational backgrounds were also apparent in all but two of the cases included in the study. It was easier for the firms to interact with the university when firm representatives themselves were scientists. Common organisational knowledge bases were apparent again in all but two of the cases covered by the study. For example, in the case of an MNC, interactions with the university were facilitated by the deep technological knowledge possessed by the company. Additionally, the spin-off was in the process of applying for legal protection of its own IP in parallel with the patent licensing process.

In researching the role of institutions in international collaborations, I found that institutional distance between actors' environments influences international university–industry knowledge transfer in different forms (regulatory, normative, cognitive) and levels (state, organisational, individual). The consequences of interactions (success or failure) are the result of a combination of these factors, rather than one element alone.

3.2 The relationship between geographical space and institutional factors[1] in international university–industry knowledge transfer

In Article II, I study the role that geographical proximity plays in relation to non-spatial proximity dimensions (including institutional factors) in the context of international contract research, thereby contributing to answering RQ2 and, in terms of the discussion of changes over time in proximities, RQ4. I base the article on the notion that in addition to spatial proximity between the actors, other, non-spatial forms of proximity can be identified (Boschma, 2005; Knoben & Oerlemans, 2006). Additionally, non-spatial proximities (cognitive, organisational, social and institutional) can exist together with spatial proximity, or they can compensate for its absence (Hansen, 2015). Non-spatial proximities can also develop and change with time (Boschma, 2005; Steinmo & Rasmussen, 2016).

Nine cases of contract research in innovation-driven sectors between Tallinn University of Technology, representing a typical technical university in Central and Eastern Europe, and domestic and international enterprises were analysed. The interview and document analysis results showed that the complementarity between spatial and non-spatial forms of proximity occurred for cognitive, organisational, social and institutional proximity (Table 3). Domestic contract research was mostly characterised by similarities in the educational background of individuals, but not by shared R&D experiences and technology at the organisational level. This can be explained by the small country context and the fixed pool of academics at the university. The R&D experiences of domestic enterprises (mainly SMEs) were expected to develop step by step when the university had proven its usefulness for the firm, mutual trust had increased, and both the university and the firm had engaged in more long-term cooperation. Organisational proximity was also found to co-exist with geographical proximity. Especially larger firms with more resources, but also more R&D-intensive firms like subsidiaries of foreign corporations and academic spin-offs, tended to belong to the same

[1] Institutional factors in Article II entailed institutional and cognitive proximity (Boschma, 2005) that corresponded in the main to the operationalisation of regulatory, normative and cognitive institutions (Scott, 1995, 2008) employed in Article I.

professional networks with the university. Additionally, social proximity was apparent in the form of previous organisational- and individual-level contacts. The initiation of cooperation without former contacts was possible in one the cases, but it required some time for the SME to be reassured that their idea had value and that it was safe to share it. Finally, institutional proximity was mostly not apparent at the individual level. The case of an academic spin-off was an exception, as it had grown out of the same university unit with which it cooperated. However, sharing a similar regulatory framework and national culture meant that institutional proximity existed at the organisational level.

Geographical proximity was substituted by cognitive and social proximity and, to a limited extent, by institutional proximity. International contract research was characterised by R&D and technological similarities at the organisational level. Foreign enterprises had long-term R&D experience and patents in the same area as the university. The substitution of geographical proximity by cognitive proximity was also apparent at the individual level as similarities in educational background. The R&D personnel of the firms were likely to include individuals with similar engineering backgrounds as university personnel. Similar to domestic cooperation, social proximity was also important in international contract research. In the cases included in the study, the foreign firms had previous contacts with public sector organisations or with academics at the university. In one of the cases in which social proximity was absent, cooperation ended prematurely after the preliminary study without a further cooperation agreement. Lastly, in one of the cases, there was some evidence of geographical proximity being substituted by institutional proximity. This occurred mainly as similarities in work ethics (entrepreneurial spirit) and increased over time through learning about foreign culture and the increased social proximity (trust) enabled by temporary geographical proximity. It also contributed to the transfer of tacit knowledge.

Table 3. *Complementarity and substitution between spatial and non-spatial forms of proximity*

Relations between spatial and non-spatial proximity	**Geographical proximity**	**Cognitive proximity**		**Organisational proximity**	**Social proximity**		**Institutional proximity**	
	Spatial closeness	R&D and technology	Education	Common formal networks	Organi-sational contacts	Personal contacts	Institu-tional setting	Individual norms
Complementarity	Case 1 Case 3 Case 4 Case 5 Case 7	 Case 5	Case 1 Case 3 Case 5 Case 7	Case 1 Case 3 Case 5	Case 1 Case 3 Case 5 Case 7	Case 1 Case 3 Case 5 Case 7	 Case 3 Case 4 Case 5 Case 7	 Case 5
Substitution		Case 2 Case 6 Case 8 Case 9	Case 2 Case 6 Case 9		Case 2 Case 8 Case 9	Case 2 Case 8 Case 9		Case 2

Source: Article II (Küttim, 2016).

I concluded, thus, that domestic and international interactions were formed based on different interaction patterns. For domestic contract research, social, organisational and institutional proximity existed simultaneously with geographical proximity and facilitated the increase of cognitive proximity in the form of increased R&D experiences over time. International cooperation, in which geographical proximity was absent, benefitted from the existence of cognitive and social proximities. There was also evidence of an increase of shared values and norms over time.

3.3 The role of structural factors in relation to institutional factors[2] in international university–industry knowledge transfer

In Article III, I examine the institutional and structural features of knowledge networks by relating the brokerage roles of actors to the organisation type and location in biotechnology and software networks, thereby contributing to addressing RQ3 and, in terms of the discussion of differences between different time periods, to addressing RQ4. I relied on the notion that non-structural and structural features of networks influence knowledge flows when actors partner across institutional (countries, industries, technologies) and structural boundaries (Balachandran & Hernandez, 2018). I distinguished between sectoral networks with analytical and synthetic knowledge bases (Asheim & Gertler, 2005; Asheim & Coenen, 2005).

An analysis of EU-funded collaborative research projects in the areas of biotechnology and software in which organisations from the Baltic States had participated, from 1995 to 2016, was undertaken. The results of social network analysis indicated that the brokerage in biotechnology networks varied across different time periods (Figs. 4–6). During the first (FP4 and FP5) and second (FP6) periods, the actors with the highest brokerage scores were higher education and research organisations from Eastern and Western Europe and Western and Northern Europe, respectively. During the third period (FP7 and H2020), these actors were public bodies from Western and Northern Europe. Enterprises were the least active brokers, and the firms with the highest brokerage scores originated from Northern and Western Europe. The organisations from the Baltic States that acted as brokers were mostly universities. Only three enterprises acted as brokers in biotechnology networks (FP6).

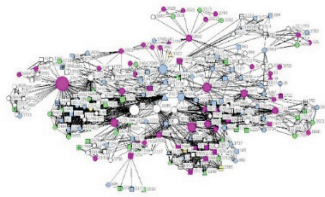

Figure 3. *Biotechnology network 1995–2003 (FP4, FP5) (N=228).*

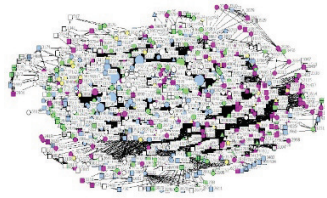

Figure 4. *Biotechnology network 2003–2007 (FP6) (N=1221).*

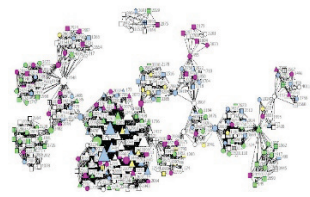

Figure 5. *Biotechnology network 2007–2016 (FP7, H2020) (N=280).*

Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; Node size – based on total normalised brokerage scores

Source: Article III (Küttim et al., 2020).

[2] Institutional factors in Article III mean similarities in organisation type (Ponds et al., 2007; Balland, 2012) that are different from the operationalisations employed in Articles I and II because of the limitations of the secondary dataset used in Article III.

According to the results of a Kruskal-Wallis H test, there was a statistically significant difference in brokerage scores for the different organisation types in the case of all four brokerage roles (i.e. coordinator, gatekeeper, consultant and liaison). The post-hoc Tamhane T2 test showed that in the first two periods (FP4 and FP5; FP6), universities and research organisations frequently acted as brokers. In the third period (FP7 and H2020), public bodies held more strategic positions in the network. Universities brokered in their own region and between regions, while public bodies brokered between different regions. The enterprises were underrepresented as brokers when compared to the proportion of enterprises in the biotechnology networks.

In the software network, the social network analysis indicated that the actors with the highest brokerage scores were again mainly higher education and research organisations (Figs. 7–9). These actors originated mostly from Western and Southern Europe. Enterprises in software had higher brokerage scores than these in biotechnology and were primarily located in Western Europe. The actors from the Baltic States with the highest brokerage scores were higher education and research organisations, such as in biotechnology. Different from biotechnology, alongside classical universities, technical specialised universities were also active. Seven enterprises acted as brokers, which is more than in biotechnology.

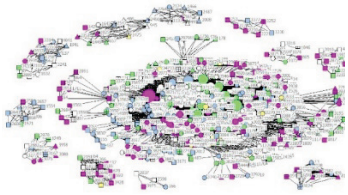

Figure 6*. Software network 1995–2003 (FP4, FP5) (N=921).*

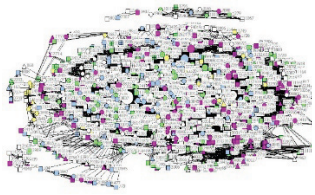

Figure 7. *Software network 2003–2007 (FP6) (N=1316).*

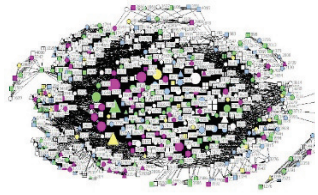

Figure 8. *Software network 2007–2016 (FP7, H2020) (N=488).*

Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; Node size – based on total normalised brokerage scores

Source: Article III (Küttim et al., 2020).

According to the results of the Kruskal-Wallis H test, there was a statistically significant difference in brokerage scores for the different organisation types in the case of all four brokerage roles, similarly to biotechnology. The results of the post-hoc Tamhane T2 test showed that higher education and research organisations held the most strategic positions as brokers during all three periods, which was dissimilar from biotechnology networks. Again, universities and research organisations brokered more frequently within their own regions and across different regions. Like in biotechnology, the proportion of enterprises among the brokers was lower than the proportion of enterprises in the entire network.

As a result of the analysis, I concluded that universities were overrepresented in both sectoral networks as brokers, while enterprises were underrepresented. The biotechnology networks differed in terms of very active public sector organisations that had high brokerage scores. Brokers with a larger geographical reach, i.e. connecting actors located in different regions, were in both sectors mainly higher education and research organisations and, in biotechnology, also public bodies.

4 Discussion

In the thesis, I studied both the influence of the organisational field for the actors and the relationships among the actors across fields and spatial distances. In other words, I explored the effect of institutional distance on the actors as well as the characteristics of the networked relations that were formed. This does not comprehensively explain, however, why university–industry interactions at the intersection of organisational fields succeed or fail, as there are also non-institutional factors. Cooperation might discontinue because of actor characteristics (absorptive capacity, size, experiences, R&D intensity, aims and strategic intent), technological complexity, lack of information related to commercial applicability, the amount of further investments needed in developing the technology, and/or changing economic realities and market demand.

The role of institutional factors in international university–industry knowledge transfer

Regarding how regulatory, normative and cognitive institutions foster international university–industry knowledge transfer, I found that these institutions play different roles depending on the phase of interactions. In Article I, I confirmed the results of previous studies (Bjerregaard, 2010; Malik, 2013), stating that institutional differences in the actors' national contexts mattered for international commercialisation. The existence of a common linguistic space and a national legislative framework were necessary conditions at the start of interactions for them to be initiated. Because of historical events, knowledge transfer across national boundaries is characterised by institutional diversity (Malik, 2013). This leads to differences in prevailing regulatory regimes and the cultural characteristics of national contexts (Ionascu et al., 2004). Such diversity is a source of behavioural uncertainty, increasing the cognitive complexity of interactions (Dow et al., 2016). I found that it was important that this uncertainty was reduced, especially in science-driven sectors and for user-enterprises. The regulatory framework was vital for the science-driven sectors as there the codified knowledge, in the form of patents employed to protect intellectual property, dominates (Wal & Boschma, 2009). It was also deemed important for the enterprises that contacted universities, as these were located in Finland, Singapore, the UK and the US. They occupied positions one, two, eight and 20, respectively, on the IPR protection measure.

In Article I, I added to previous research by demonstrating that the long-term success or failure of international commercialisations depends on shared cognitive frameworks at both the organisational and individual levels and on similar individual norms. This meant that in all but two of the cases included in the study, the organisations possessed patents in the same area, and individuals had a shared educational background. In one of the cases, coming from Estonia, the lack of these features led to the breakdown of the interactions. My research also showed that the interactions between university and industry were commonplace and were viewed positively in the respective organisational contexts of universities and enterprises. Additionally, the scientists who were employed either as academics in universities or lab researchers in enterprises were educated in the academy and were influenced by common science norms. This is a novel finding, as it illustrates how the broad concept of the organisational field of university–industry interactions (e.g. in Malik, 2013; Malik & Yun, 2017) consists of more complex organisational institutional realities at different levels.

The tacit nature of knowledge complicates it for the university to identify the possible areas for the application of this knowledge and for the enterprises to engage in knowledge transfer (Fransman, 2008). In Article IV, I showed that the channels of knowledge transfer that are less media-rich and that allow less immediate communication are less suitable for the transfer of tacit knowledge (Alexander & Childe, 2013). This is the case with patenting and licensing that involve mostly codified knowledge (Lee, 2012). In a subsequent paper focusing on commercialisation that grew out of the results of the present thesis, we concluded

that TTOs that bridge different organisational fields and facilitate university–industry cooperation have to develop capabilities for evaluating the technical as well as commercial value of inventions in different sectors and disciplines (Kalantaridis & Küttim, 2020). Related to such capabilities is the identification of entrepreneurial opportunity, which requires TTOs to be alert to opportunities, learn from failed experiments, and acquire experience in entrepreneurial venturing (Ibid., 2020). This also leads licensee firms to establish more long-term, direct relationships with academic inventors themselves (Lee, 2012). It is especially important when the route to market is not through licensing but instead via the establishment of a spin-off (Damsgaard & Thursby, 2013). Networks of academics are also important for creating a new set of linkages with established firms and for identifying cooperation partners (Lee, 2012). The continued involvement of academics contributes to the transfer of tacit knowledge that transcends what is stated in the patent description. Additionally, the enterprises should not be excluded from the commercialisation process. Firms that specialise in technology transfer can provide universities with the tools needed to evaluate university-generated knowledge from the perspective of potential entrepreneurs and investors (Owen-Smith & Powell, 2003).

The relationship between geographical space and institutional factors in international university–industry knowledge transfer

Concerning how the relationship between geographical space and institutional factors is constructed in international university–industry knowledge transfer, my analysis showed that domestic and international contract research is characterised by different dynamics regarding proximity dimensions. I confirmed in Article II, in the context of contract research conducted in Estonia, the results of previous studies (Hansen, 2015) that spatial and non-spatial forms of proximity are characterised by mechanisms of complementarity and overlap. I found that in the case of domestic cooperation, geographical proximity existed mostly simultaneously with cognitive (educational background), organisational (networks), social (former organisational and individual contacts) and institutional proximity (institutional setting). Large domestic and international companies, academic spin-out SMEs, and established SMEs have different interests and capabilities for R&D cooperation (level of specialisation, economies of scale in R&D, already existing networks) (Fransman, 2008). Geographical proximity has been found to be helpful for domestic enterprises with limited R&D capacity and experience to access the university (Hoekman et al., 2009; Slavtchev, 2013; Hansen, 2015). These ties enable local enterprises to access international knowledge sources, reduce the costs for knowledge searches, and increase their absorptive capacity and cognitive proximity (Fontes, 2005; Petruzzelli & Murgia, 2019). In addition, geographical proximity is important in R&D projects with a short time to market as opposed to long-term research projects (e.g. Broström, 2010).

From the university perspective, it is important, however, to find large R&D-intensive industrial partners outside the domestic market as well as to contribute to the development of the local economy. Universities that function, in addition to the local and regional space, at the international level must consolidate these different roles (Fromhold-Eisebith & Werker, 2013; Howells & Nedeva, 2003). My research results in Article II indicated that in international contract research, geographical proximity was substituted by cognitive (educational background and R&D experiences), social (former organisational and individual contacts) and, in some instances, by institutional proximity (values and norms). The importance of geographical proximity has been found to decline with an increase in the firm's R&D expenditure and the importance of codified basic research results (Arundel & Geuna, 2004). R&D-intensive firms are more likely to initiate collaboration with a university when they share similar technological know-how, which would compensate for the spatial

distance (Slavtchev, 2013). However, I indicated in Article IV that the channels of knowledge transfer that are more collaborative and explorative (collaborative research) require more distant knowledge bases for novelty and creativity to emerge (Petruzzelli, 2008).

I added in Article II to the existing studies (Petruzzelli, 2008; Hansen, 2015) that distinguishing between various levels of analysis (individual and aggregate), generated different results regarding complementarity and substitution effects. Namely, this difference between the results of analysis emerged for domestic cooperation but not for international interactions. Regarding domestic cooperation, I found that complementarity between geographical and cognitive proximity at the individual level is not necessarily apparent at the organisational level. This was because even though individuals shared a common educational background, organisations did not have comparable R&D experience and patents in the same area (technological similarity). Also, overlap between geographical and institutional proximity at the organisational level (similarity in institutional setting) did not always emerge at the individual level (shared values and norms). However, in the case of international cooperation, the substitution of geographical proximity with cognitive and social proximity existed at both the organisational and individual levels.

The role of structural factors in relation to institutional factors in international university–industry knowledge transfer

In terms of how structural factors, including brokerage, are related to institutional factors in international university–industry knowledge transfer, I found that the relationships between actors differed based on the sector. In Article III, I confirmed the results of previous studies, indicating that sectoral networks differ in terms of the types of central actors (Asheim & Gertler, 2005; Asheim & Coenen, 2005; Liu et al., 2013; Salavisa et al., 2012). The proportion of higher education and research organisations was higher in biotechnology networks and exceeded that of enterprises. This can be attributed to sectoral characteristics like the high complexity, uncertainty and long product–service development timeframes of biotechnology firms (Connected Health, 2015). In Article III, I confirmed Salavisa et al.'s findings (2012), which argued that biotechnology networks were more connected, centralised and clustered. In software, however, universities and enterprises were more evenly distributed. This indicated that software firms also contribute to R&D and to the generation of new knowledge. Software networks were considerably more fragmented and more often centred around enterprises, as also stated by Salavisa et al. (2012).

Although the previous studies (Liu et al., 2013; Herstad et al., 2014; Asheim, 2007; Coenen et al., 2006) agree on the different geographical scope of sectoral networks, my results from Article III did not confirm this finding. In biotechnology as well as in software, the proportion of actors from outside Europe was the lowest, while that of actors from Western Europe was the highest. This can be attributed to the characteristics of the collaborative research analysed. In Article IV, I showed that larger and longer-term collaborative research projects interest universities due to the more basic nature of the research (Caloghirou et al., 2001). However, the formation of EU research projects is regulated by framework programmes' qualification criteria and funding rules (Balland, 2012). Also previous studies have found that actors in EU projects are more likely to cooperate when they have already collaborated or when they are located in close proximity in the network (i.e. they share social proximity) (Autant-Bernard et al., 2007). The different participation rates of actors from different countries can also be attributed to the differences in economic development and to the distribution of public and private R&D funding (Blažek & Kadlec, 2019).

While enterprises were active participants in the studied projects (especially in software), the central brokerage roles were primarily fulfilled by education and research organisations. These organisations more often brokered over larger geographical distances. Doing so offered

them advantages and disadvantages in both sectoral contexts, such as access and control over the flow of information, and the ability and responsibility to connect different parts of the network (Prell, 2012). This indicates how enterprises may benefit, in a small country setting, like Estonia, that is not central in terms of innovation and which is mainly outside the major sectoral clusters, from partnering with these universities to access global networks (Fontes, 2005). Different from software, public bodies acted more often as brokers in biotechnology. This can be attributed to biotechnology originating from university labs but being substantially supported by governmental investments (Owen-Smith & Powell, 2004). In Article III, I added to previous studies by discussing the central brokerage role of higher education and research organisations (Kauffeld-Monz & Fritsch, 2013; Chen et al., 2015), that this did not depend on the sector. However, the central brokerage role of public bodies was sector-specific, being characteristic only of biotechnology.

The role of time in the interactions of actors from multiple fields in international university–industry knowledge transfer

With regard to how time influences the interplay between the components of the organisational field in international university–industry knowledge transfer, I concluded it inhibits as well as enables cooperation. I confirmed the findings of previous research (McAdam et al., 2017; Ellwood et al., 2017), demonstrating that path dependency constrained the activities of both universities and enterprises to past areas of success. I illustrated it based on international commercialisation in Article I that employed a detailed operationalisation of institutional factors. International commercialisation was limited by the norms, cognitive frameworks and knowledge bases of actors that had developed over time and were difficult to change. These activities inhibited new interactions from emerging, as they depended largely on the knowledge-generating and networking abilities of the individual academics at universities. The question here is how path dependency influences the route of university-generated knowledge to market. I found that path dependency and the cumulative nature of knowledge restricts the licensing of new, early-stage generic technologies to existing firms. Enterprises tend to develop absorptive capacity in a rather narrow sectoral setting (Kenney & Patten, 2009), and developing such capacity requires a deliberate effort (Cohen & Levinthal, 1990). However, it may lead universities to establish spin-offs if the academic entrepreneurs themselves are able to assemble and develop the necessary resources, and to create entrepreneurial opportunities (Baglieri & Lorenzoni, 2014; Vohora et al., 2004). In emerging economies like Estonia, productivity growth is influenced mainly by external factors, such as regional spill-overs and convergence with more developed neighbours; while in older EU member states, productivity is based more on internal resources, including human capital and R&D (Männasoo et al., 2016). Since latecomer firms cannot remain recipients of knowledge in a global production network, they must invest in autonomous learning to become contributors in the global innovation network (Ray et al., 2017). I find this as contributing to knowledge transfer, as there are limited past areas of success to constrain the development of university–industry interactions.

The enabling dimension of time was apparent in Article II, where I conformed the findings of previous studies (Hoekman et al., 2009; Slavtchev, 2013; Hansen, 2015; Boschma, 2005) in that different types of proximities can develop over time. On the one hand, in domestic contract research, geographical proximity enabled other forms of non-spatial proximity to emerge over time. Geographical proximity, co-existing with organisational and social proximity, increased cognitive proximity in terms of mutual understanding and trust. This allowed domestic SMEs with limited R&D intensity and university–industry cooperation experience to access university-generated knowledge. On the other hand, in international cooperation, social and in some cases also institutional proximity increase over time due to increased trust and understanding of mutual institutional logics (Slavtchev, 2013; Hansen,

2015). Temporary geographical proximity has been claimed to contribute over time to increasing the understanding of partners' norms and the organisation of work (Torre, 2008). My results from Article II indicated that the regular visits by the foreign enterprise compensated for the absence of geographical proximity and contributed to increased institutional proximity in the form of shared values, norms and trust, and also the exchange of tacit knowledge. Trust is more likely to increase in bilateral collaborations than in cases of cooperation involving multiple partners (Balland, 2012). I find that the development of trust-based relations between partners is related mostly to the increase in social proximity.

The consequences of cross-field interactions in international university–industry knowledge transfer

In terms of the consequences of cross-field interactions, the institutionalisation of activities was the hardest goal to achieve in international commercialisation. Article I showed that the institutionalisation of international commercialisation, either in universities or enterprises, was the outcome of the joint effect of organisational rules, strategic intent and the volume of the IP held by the organisation. The novelty I added with Article I was that, in some instances, institutionalisation occurred in the form of non-practising entities acting as innovation intermediaries without sharing common knowledge bases or shared injunctive norms with the university. These entities can be seen, on the one hand, as facilitating connections between inventors whose inventions have not been deployed and user-enterprises (Spulber, 2012). On the other hand, they can be viewed as generating extra costs and discouraging innovation (Meurer & Bessen, 2014). They occupied a position between the university and user-enterprise organisational fields, mainly in innovation-driven sectors and in the case of the smallest university contexts (Tallinn University of Technology and IIT Delhi). Their importance depended on the size of their own IP portfolio compared to the limited knowledge-generating capabilities and modest volume of protected knowledge possessed by these universities. This was different from university-led institutionalisation, apparent in large knowledge-producing universities (University of Manchester) and in science-driven systems. The activities of non-practising entities were, nevertheless, limited due to the difference in institutional factors, such as their own knowledge base, injunctive norms and cognitive frameworks.

Regarding new field formation, I added to previous studies addressing the institutionalisation of knowledge transfer at universities (Pinto, 2017; Baldini et al., 2014) by showing that it was dependent on the channel of knowledge transfer and university/ sectoral contexts. The international commercialisation activities discussed in Article I did not lead to the emergence of a new, permanent organisational field. This was the case especially in smaller university contexts. It was inhibited by the path-dependent nature of normative and cognitive frameworks, the limited number of patents, and the lack of strategic intent. An additional obstacle was the nature of interactions, in which user-enterprises licenced a technology whose development they had not participated in, and the interactions had a relatively short timespan. In this case, the organisational field was not always in use, but came alive when organisations decided to interact (Wooten & Hoffman, 2017). In the case of contract research and collaborative research projects, new joint regulations and institutionalised processes emerged, as these channels involved higher degrees of participation of actors over a longer period of time. As I indicated in Article IV, these interactions develop from the exploration stage to the integration stage (Sorensen & Hu, 2014). In the cases I explored in Article II, contract research-related cooperation continued in several phases and developed further into other areas (collaborative research, internships, student thesis, sponsorship, etc.), mainly for Estonian industry partners or MNCs operating in the country. In the case of MNCs and foreign enterprises, I uncovered instances of cooperation that had proceeded through several phases, implying formalisation and organisation. In collaborative research, core partnerships persisted over the course of different projects and funding periods.

5 Conclusion

In the thesis, I aimed to explore how actors from multiple organisational fields interact internationally as well as the consequences of such interactions. To that end, I posed four research questions: (1) How do regulatory, normative and cognitive institutions foster the international university–industry knowledge transfer? (2) How is the relationship between geographical space and institutional factors constructed? (3) How are structural factors, including brokerage, related to institutional factors, and (4) Which role does time play in the interactions of actors from multiple fields in international university–industry knowledge transfer.

Different from domestic knowledge transfer, the international university–industry interactions entail two simultaneous processes: interactions across different institutional contexts as well as distant organisational fields. The former entails various national contexts, and the latter consists of different aims and institutional logics of actors. My results indicated that given the country-level differences in culture, religion, regulations, etc., the individual and organisational level similarities play a larger role for the international interactions to succeed. This is because for cooperation to take place, other factors need to compensate for the institutional distance. I found that unlike domestic interactions, international cooperation required both the individual and organisational level similarities. This was apparent in shared cognitive and social frameworks manifested as similar educational background, former contacts and mutual acquaintances (at the individual level) as well as similarities in R&D experiences and technology, and partners in common (at the organisational level).

I addressed in the thesis the role institutional differences play for the actors as well as the relationships that develop between the actors across fields and spatial distances, in the context of international university–industry knowledge transfer. This dual viewpoint enabled me to examine the conditions that provide the basis for initiating international cooperation as well as the characteristics of networked interactions that emerge between the actors.

Based on the above, I make the following theoretical contributions:

- Regarding the effect of institutional distance on the actors, a common language and legislative framework were important for university–enterprise interactions to be initiated (Table 4). However, their more long-term success or failure depended on shared normative (descriptive and injunctive norms) and cognitive institutions (educational background, patents in the same area), developed as a result of path-dependent trajectories (Article I). Furthermore, I found that different from domestic interactions, international cooperation required similarities at both the individual and organisational levels. In international cooperation, the substitution of geographical proximity with cognitive and social proximity occurred both at the individual (shared educational background, former contacts and mutual acquaintances) and organisational levels (similarities in R&D experiences and technology, partners in common) (Article II).

***Table 4**. The effects of institutional distance for cooperation stages*

	Regulative institutions	Normative institutions	Cognitive institutions
Early stages of cooperation	IP regulations		Language
Later stages of cooperation		Descriptive and injunctive norms	Educational background; Patents in the same area

- In Articles I and II, I decreased the dependence of research results on the operationalisations used by employing multiple levels of analysis. In Article I, I developed further the idea that the diversity of actors' institutional context, operationalised in Malik (2013) and Malik and Yun (2017) only as state-level differences, influences the university–industry cooperation. This was done by employing a more detailed operationalisation of elements of institutions (the regulatory, normative, and cognitive) at several levels (the individual, organisational and country). This operationalisation illustrated how the broad concept of organisational field consists of different elements of institutions at different levels not employed previously in multi-county studies. In Article II, I distinguished simultaneously between individual and organisational levels of proximity dimensions and showed how that led to different results regarding domestic and international knowledge transfer. By operationalising proximity dimensions at several levels, I advanced the findings of Petruzzelli (2008) and Hansen (2015) that operationalised specific proximity dimensions either at individual or organisational levels.
- In terms of the characteristics of relationships among the actors, I found that sectoral differences existed in the brokerage roles of actors. Higher education and research organisations connected actors over greater geographical distances both in biotechnology and software networks, while public bodies did that only in biotechnology (Article III). This indicated the central brokerage role of universities existed in the EU research projects across sectors, and that of public bodies did not. I advanced the findings of previous studies, e.g. Kauffeld-Monz and Fritsch (2013) and Chen et al. (2015), addressing the brokerage roles of different types of organisations in accessing distant knowledge, by adding the comparison of different sectors in international context. I showed that the brokerage role of higher education and research organisations is more universal, while that of other types of actors (e.g. public bodies) is more sector-specific.
- An additional contribution concerning the relationship among the actors was that the institutionalisation of international commercialisation required the joint effect of organisational rules, strategic intent and the volume of IP held by the organisations. This institutionalisation is mostly led by universities, especially in the science-driven sectors and larger university contexts. I added with the thesis the novel contribution that, in some instances, institutionalisation was found to additionally occur in the form of non-practising entities, which acted as innovation intermediaries without shared normative or cognitive institutions (Article I). This happened in the innovation-driven sectors and smaller university contexts. These intermediaries can be seen only as a temporary solution to the institutionalisation problem (with pooling resources with other universities in the region being a more viable option). This was

shown in Article I, where the different norms led to the break-down of negotiations between the academic and commercially-driven knowledge user.

- The consequences of interactions across fields depended on the channel of knowledge transfer and the university/ sectoral context. The novel contribution compared to studies addressing the institutionalisation of knowledge transfer, such as Pinto (2017) and Baldini et al. (2014), was taking the international approach and comparing various channels of knowledge transfer. I found that institutionalisation of international commercialisation was less apparent in the smaller university contexts and in innovation-driven sectors (Article I). There the new organisational field remained largely dormant. In the case of contract and collaborative research, however, also the smaller universities had declared internationalisation as part of their R&D strategy and had developed corresponding organisational rules, structures and practices. Contract research was found to broaden into other areas of cooperation (Article II) and collaborative partnerships to persist throughout different funding periods (Article III).

My thesis makes the following empirical contributions:

- I added the new empirical context of the emerging economy of Estonia (Articles I and II) and the Baltic States (Article III) to the studies of international university–industry knowledge transfer. This is an interesting context for comparative study in consideration of the relatively short time this region, which is considered an innovative periphery (Eder, 2019), has been involved in a market economy and in the strategic development of university–industry interactions. The latecomer advantage can be seen as contributing to knowledge transfer, as there are limited past areas of success to constrain the development of university–industry interactions.
- I also added a comparison of Estonia with other developing and developed economies, including India, Portugal and the UK (Article I). These national contexts represented diversity in terms of institutional development (Audretsch et al., 2014), from advanced knowledge-generating capabilities (UK) to emerging knowledge-generating capabilities (India), and from globally leading (UK) to a relatively small (Estonia). This highlighted the smallness effects of country and university contexts in Estonia, where unlike in developed countries, the TTOs are not the leading actors in international knowledge transfer activities and international commercialisation is under-developed compared to other forms of knowledge transfer.

I make in the thesis the following managerial or practical contributions:

- In terms of commercialisation, I emphasised next to TTOs, the role of academics and knowledge-using enterprises, notably in smaller university contexts (Article I). This widens the range of cooperation partners, facilitates the transfer of tacit knowledge, and the assessment of the commercial value of the university-generated knowledge. It requires the development of entrepreneurship skills of academics (involving entrepreneurial opportunity, market information, networks, uncertainty and ambiguity of information, visioning and conceptualising abilities). And, developing a network with enterprises to assist in the assessment of commercialisation potential of technologies developed in the academia, as they are in their more narrow area closer to the market than the university.

- For contract research, although geographical proximity is not a necessary condition for cooperation to be initiated, it does facilitate the development of other types of proximities and the transfer of tacit knowledge (Article II). In that vein, I found temporary geographical proximity in the form of regular face-to-face contacts to be beneficial in international interactions, especially in innovation-driven sector.
- In terms of collaborative research, my results indicated the benefits of having higher education and research organisations with a larger geographical reach and access to knowledge flows as consortium members (Article III). This reduces knowledge accession costs and enables the organisational learning of local firms (SMEs mainly, not experienced in R&D) regarding R&D activities regardless of the sector.

There are several limitations and implications for further research. I examined in the thesis the interplay of institutional, geographical, structural and temporal factors for different channels of knowledge transfer separately in individual studies. Further analysis should address in a more detailed way the interplay between institutional factors and the types of knowledge being transferred. This is related to comparatively examining the explorative and exploitative forms of knowledge transfer, especially with regard to the different phases of cooperation and the corresponding characteristics of knowledge. Another avenue for further research is to focus on the links between knowledge production, transfer and appropriation in the context of entrepreneurial opportunity. The commercialisation of university-generated knowledge with a clearer route to market provides a context for this research approach. Future research should address the interconnections between sectoral characteristics, opportunity identification (discovery and creation) and commercialisation mechanism (licensing or spin-off creation). As current study approached knowledge transfer mainly from the university perspective, further research on enterprises is warranted. The developing country context, with firms less constrained by technological path dependency, provides new empirical insights for organisational learning as well.

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Abstract

International university-industry knowledge transfer

University–industry linkages are increasingly being established over great geographical distances and across national boundaries, as the central locus of innovation has become international and dependent upon linkages between different types of organisations and sources of knowledge (Heitor, 2015). Access to external sources of knowledge, especially foreign knowledge, has been found to decrease the risks of spatial and cognitive lock-in (Petruzzelli & Murgia, 2019) and lead to new path development (Petruzzelli & Murgia, 2019; Trippl et al., 2018). This enables universities to establish and participate in global networks and to pursue international markets to withstand global competition (Garrett-Jones & Turpin, 2012). For their part, enterprises are able to be more competitive in international markets by responding to progress in science and technology (Mason & Wagner, 1999) and engaging in new product development (Santoro et al., 2017).

The research problem of the thesis is related to the notion that the transfer of knowledge across institutional boundaries, like countries and sectors, involves actors with different institutional logics and types of capital (Scott, 2015). This results in costs related to both accessing novel external information and integrating it (Balachandran & Hernandez, 2018). The costs of accessing and 'translating' knowledge result not only from institutional factors but also from the tacit nature of knowledge making, which, for the university, complicates the identification of possible areas for the application of knowledge and involves transactions costs for the firms (Fransman, 2008).

There is a research gap in our understanding in detail how the actors that have different aims and operational logics interact internationally. Although previous research has recognised the co-existence of shared structural interactions and common cognitions in an organisational field, most empirical studies have emphasised one component over the other and have neglected the temporal component, which would have enabled the shared network structure to result in collective cognition (Coraiola et al., 2018). Compared to the structural features of the shared networks, the institutional characteristics of organisations and their geographical locations, which alter the characteristics of knowledge flows, have received limited attention (Owen-Smith & Powell, 2004). Additionally, analysing structural and institutional factors separately fails to address their combined influence (Balachandran & Hernandez, 2018).

Based on the above-mentioned context, the aim of the thesis is to explore how actors from multiple organisational fields interact internationally as well as the consequences of such interactions. Related to the aim, I posed the following research questions:

RQ1: How do regulatory, normative and cognitive institutions foster international university–industry knowledge transfer?

RQ2: How is the relationship between geographical space and institutional factors constructed in international university–industry knowledge transfer?

RQ3: How are structural factors, including brokerage, related to institutional factors in international university–industry knowledge transfer?

RQ4: What role does time play in the interactions of actors from multiple fields in international university–industry knowledge transfer?

My thesis consists of four articles. Article I provides the means for answering RQ1 and RQ4; Article II contributes towards answering RQ2 and RQ4; Article III addresses RQ3 and RQ4; and Article IV is concerned with all the RQs. Three of the articles explore various channels of knowledge transfer: commercialisation (Article I), contract research (Article II) and collaborative research (Article III). Additionally, these articles address the sectoral divide

in university–industry interactions, with Articles I and III differentiating between sectors with analytical and synthetic knowledge bases, and Article II focusing on the synthetic knowledge base.

My research results indicated that the collaborations require shared regulatory framework and language of communication (Article I). Additionally, the similarities in cognitive and normative institutions (shared education background and R&D experience, common norms of actors) largely defined the outcome of commercialisation of university-generated knowledge. As these were path dependent and hard to change, this limited also the scope for increasing international knowledge transfer activities. In case the institutionalisation of international commercialisation had not been led by universities (at the account of organisational rules, strategic intend and volume of IP), it allowed non-practicing entities to act as innovation intermediaries.

I also found that domestic and international contract research between university and enterprises were formed based partly on different interaction patterns between proximity dimensions (Article II). Different overlap and substitution mechanisms between spatial and non-spatial forms of proximity could be observed. For domestic contract research the existence of geographical, social and organisational proximity could compensate for the lack of other types of proximities and facilitate the increase of cognitive proximity in the form of increased R&D experience over time. International cooperation, where geographical proximity was absent, benefitted from the existence of cognitive and social proximities. Regarding institutional factors, international contract research was characterised by differences in institutional settings (due to location), but with some evidence of increase of shared values and norms at individual level over time.

Networks with different institutional characteristics were formed in different sectors (Article III). I concluded that biotechnology and software knowledge networks were similar in terms of their geographical reach, but differed regarding the institutional factors. The actors with the highest brokerage scores were located in Western, Northern and Southern Europe. Actors from outside of Europe were the least represented in both sectors. The higher education and research organisations were over-represented in both sectoral networks as brokers, while enterprises were under-represented. Brokers with larger geographical reach, i.e. connecting other-wise unconnected actors located in different regions, were in both sectors mainly higher education and research organisations, and also public bodies in biotechnology.

I contribute theoretically to international university–industry knowledge transfer by combining two perspectives: i) the influence of the organisational field on actors, and ii) relationships among the actors across fields and spatial distances.

Regarding the effect of institutional distance on the actors, I propose in the thesis a more detailed operationalisation of institutions consisting of the regulatory, normative, and cognitive elements at the individual, organisational and country levels (Article I). With this operationalisation I illustrated how the broad concept of organisational field consists of different elements of institutions at different levels not employed previously in studies of international knowledge transfer. I also showed that the long-term success or failure of international interactions depended on shared individual norms and cognitive frameworks as well as organisational knowledge bases (Article I). Different from domestic cooperation, international collaboration required similarities at both the individual and organisational levels (Article II).

As to the characteristics of relationships among the actors, I brought forth the differences between various types of organisations in their ability to connect actors and build networks internationally (Article III). I showed with my research that the brokerage role of higher education and research organisations was more universal, while that of public bodies was

sector-specific. As for the consequences of interactions, the comparative approach led me to the finding that institutionalisation of international commercialisation was less apparent in smaller university contexts and in innovation-driven sectors (Article I). International contract and collaborative research, however, was more institutionalised even in the smaller universities (Article II).

I also empirically contribute**,** to studies of international university–industry knowledge transfer, the context of the emerging economy of Estonia (Article II) in comparison with economically more developed countries (Article I, Article III). Estonia represents an interesting context for comparative research with respect to its relatively recent strategic development of university–industry interactions and latecomer firms that need to invest in autonomous learning. What is specific about Estonia, is also the smallness of country and university contexts, where unlike in developed countries, the TTOs are not the leading actors in knowledge transfer activities and commercialisation is under-developed compared to other forms of knowledge transfer.

Regarding managerial and practical implications, I propose in the thesis the idea that knowledge transfer goes beyond market-based transactions led by the TTO (Article I). Successful transfer of knowledge requires, especially in smaller university contexts, input from other actors as well, like academics and enterprises. It requires the development of entrepreneurship skills of academics. And, developing a network with enterprises to assist in the assessment of commercialisation potential of technologies developed at the academia. Additionally, although much of the knowledge transfer takes place across spatial distances, I found it is nevertheless facilitated in innovation-driven sectors by temporary geographical proximity (Article II). And, in a small country setting, firms have different routes toward entering international knowledge networks, including cooperating first with local universities (Article III).

Lühikokkuvõte
Rahvusvaheline ülikooli ja ettevõtete vaheline teadmussiire

Ülikoolid ja ettevõtted teevad üha enam koostööd suurte vahemaade tagant, ületades riigipiire, sest innovatsiooni kese on muutunud rahvusvaheliseks, sõltudes koostööst eri tüüpi organisatsioonide vahel ja juurdepääsust teabele (Heitor, 2015). Juurdepääs välistele teadmusallikatele, eriti rahvusvahelisele teabele, vähendab ruumilise või kognitiivse kapseldumise riski (Petruzzelli & Murgia, 2019) ja võimaldab leida uusi arenguteid (Petruzzelli & Murgia, 2019; Trippl et al., 2018). See aitab ülikoolidel luua globaalseid võrgustikke ja tegutseda rahvusvahelisel turul tulemaks toime globaalse konkurentsiga (Garrett-Jones & Turpin, 2012). Ettevõtted on samuti rahvusvahelisel turul konkurentsivõimelisemad ning käivad kaasas teaduse ja tehnoloogia arenguga (Mason & Wagner, 1999; Santoro et al., 2017).

Doktoritöö uurimisprobleem tuleneb asjaolust, et teadmussiire, mis toimub üle institutsionaalsete piiride nagu riigid ja sektorid, hõlmab erineva institutsionaalse loogika ja kapitaliga osapooli (Scott, 2015). See toob kaasa kulud, mis on seotud nii uuele infole juurdepääsu kui ka selle kasutamisega (Balachandran & Hernandez, 2018). Teadmusele ligipääsemise ja selle 'tõlkimisega' seotud kulud ei tulene ainult institutsionaalsetest teguritest, vaid ka vaiketeadmuse (*tacit knowledge*) olemasolust, mis ei ole kirjapandud ja raskendab seetõttu ülikoolidel teadmusele rakendusvõimaluste leidmist ja tekitab ettevõtetele kulusid selle kasutamisel (Fransman, 2008).

Uurimislünk seisneb erinevate eesmärkide ja institutsionaalse loogikaga ning eri riikides ja institutsionaalsetes keskkondades paiknevate osapoolte koostöö mõistmisel. Kuigi eelnevad uuringud on toonud välja võrgustiku struktuuri ja ühiste arusaamade koosesinemise organisatsiooni väljal (*organisational field*), on enamik uuringuid rõhutanud ühe komponendi olulisust võrreldes teistega ega ole pööranud piisavalt tähelepanu ajale ja selle rollile (Coraiola et al., 2018). Võrreldes teadmuse liikumist mõjutavate võrgustike struktuuriliste omadustega on organisatsioonide institutsionaalsed eripärad ja nende asukoht pälvinud vähem tähelepanu (Owen-Smith & Powell, 2004). Lisaks ei võimalda struktuuriliste ja institutsionaalsete tegurite eraldi analüüsimine arvesse võtta nende ühismõju (Balachandran & Hernandez, 2018).

Minu doktoritöö eesmärgiks on analüüsida, kuidas erinevatel organisatsiooni väljadelt tegutsevad osapooled rahvusvahelist koostööd teevad ning mis on selle tagajärjed. Doktoritöös otsitakse vastuseid järgmistele uurimisküsimustele:

RQ1: Kuidas toetavad rahvusvahelist ülikooli ja ettevõtete vahelist teadmussiiret regulatiivsed, normatiivsed ja kognitiivsed institutsioonid?

RQ2: Milline on rahvusvahelises ülikooli ja ettevõtete vahelises teadmussiirdes geograafilise ruumi ja institutsionaalsete faktorite vaheline seos?

RQ3: Kuidas on rahvusvahelises ülikooli ja ettevõtete vahelises teadmussiirdes struktuurilised ja institutsionaalsed tegurid omavahel seotud?

RQ4: Millist rolli omab rahvusvahelises ülikooli ja ettevõtete vahelises teadmussiirdes aeg erinevatelt organisatsiooni väljadelt pärit osapoolte koostöös?

Doktoritöö koosneb neljast artiklist. Artikkel I võimaldab vastata uurimisküsimustele 1 ja 4, artikkel II panustab uurimisküsimustesse 2 ja 4, artikkel III käsitleb uurimisküsimusi 3 ja 4 ning artikkel IV on seotud kõigi nelja uurimisküsimusega. Artiklid käsitlevad erinevaid teadmussiirde kanaleid: kommertsialiseerimist (artikkel I), lepingulist koostööd (artikkel II) ja koostööprojekte (artikkel III). Artiklites on tehtud vahet ka sektorite vahelisel erinevusel ülikooli ja ettevõtete koostöös, sest artiklites I ja III on eristatud analüütilise (*analytic*) ja sünteetilise (*synthetic*) teadmiste baasiga sektoreid ning artikkel II keskendub sünteetilise teadmiste baasiga sektorile.

Minu doktoritöö tulemused näitasid, et rahvusvaheliseks kommertsialiseerimiseks oli vajalik sarnane regulatiivne raamistik ja ühine keeleruum (artikkel I). Lisaks sõltus ülikooli ja ettevõtete koostöö edukus sarnastest kognitiivsetest ja normatiivsetest teguritest (sarnane hariduslik taust ja T&A kogemused, sarnased normid). Kuna need on rajasõltuvad ja raskesti muudetavad, takistavad need rahvusvahelise teadmussiirde laienemist. Kui rahvusvahelise kommertsialiseerimise institutsionaliseerimist ei juhtinud ülikoolid (toetudes organisatsiooni tasandi reeglistikule, strateegilistele eesmärkidele ja piisavale intellektuaalomandile), võimaldas see tegutseda vahendajatel, kes ei võta ise intellektuaalomandit kasutusele, vaid müüvad seda edasi teistele ettevõtetele.

Riigisisest ja rahvusvahelist lepingulist koostööd iseloomustasid erinevad läheduse kombinatsioonid (artikkel II). Mistõttu toimisid erinevalt ruumilise ja mitte-ruumilise läheduse (*spatial and non-spatial proximity*) kattumise ja kompenseerimise mehhanismid. See tähendab, et siseriikliku koostöö puhul kompenseeris geograafiline lähedus koos sotsiaalse ja organisatsioonilise läheduse kognitiivse läheduse puudumist osapoolte vahel. Samuti võimaldas see kognitiivsel lähedusel aja jooksul kasvada. Rahvusvahelise koostöö puhul, kus geograafiline lähedus puudus, asendas seda kognitiivne ja sotsiaalne lähedus. Rahvusvahelist koostööd iseloomustas üldiselt institutsionaalse läheduse puudumine, kuna organisatsioonid paiknesid erinevates institutsionaalsetes keskkondades. Siiski võis aja jooksul märgata sarnaste individuaalsete väärtuste ja normide kasvu.

Eri sektorites tekkisid erinevate institutsionaalsete teguritega võrgustikud (artikkel III). Biotehnoloogia ja infotehnoloogia võrgustikud sarnanesid oma geograafilise ulatuse poolest, aga erinesid institutsionaalsete tegurite osas. Organisatsioonid, mis ühendasid enim omavahel mitteseotud osapooli (*brokers*), asusid Lääne-, Põhja- ja Lõuna-Euroopas. Väljaspool Euroopat asuvad organisatsioonid olid mõlemas sektoris kõige vähem esindatud. Mõlemas sektoris olid haridus- ja teadusasutused vahendajatena üle-esindatud ning ettevõtted ala-esindatud. Suurima geograafilise koostöö ulatusega organisatsioonid, kes ühendasid omavahel mitteseotud osapooli, olid mõlemas sektoris eelkõige haridus- ja teadusasutused. Biotehnoloogias olid nendeks ka avaliku sektori asutused.

Minu doktoritöö panustas teoreetiliselt rahvusvahelise ülikooli ja ettevõtete vahelise teadmussiirde mõistmisse kombineerides kahte lähenemist: organisatsiooni välja mõju osapooltele ja osapoolte vahelistele suhetele, kui osapooled tegutsevad erinevatel organisatsiooni väljadel ja institutsionaalsetes keskkondades.

Institutsionaalse konteksti mõju analüüsimiseks pakkusin doktoritöös välja institutsioonide detailsema määratluse eristades indiviidi, organisatsiooni ja riigi tasandil regulatiivseid, normatiivseid ja kognitiivseid elemente (Artikkel I). See lähenemine näitas, kuidas laiem organisatsiooni välja mõiste koosneb institutsioonide erinevatest elementidest eri tasanditel, mida rahvusvahelise teadmussiirde uuringutes ei ole varem kasutatud. Koostöö pikaajalisem õnnestumine sõltus jagatud individuaalsetest normidest ja kognitiivsetest raamistikest ning organisatsiooni tasandi teadmiste iseloomust (Artikkel I). Erinevalt siseriiklikust koostööst oli rahvusvahelise teadmussiirde puhul vajalik sarnasus nii indiviidi kui organisatsiooni tasandil (Artikkel II).

Osapoolte vaheliste suhete iseloomu osas leidsin, et eri tüüpi organisatsioonidel on erinev võimekus osapooli ühendada ja rahvusvahelisi võrgustikke luua (Artikkel III). Minu uuringu tulemused näitasid, et haridus ja teadusasutuste roll vahendajana oli üldisem, samas kui avaliku sektori organisatsioonide roll sõltus sektorist. Koostöö tagajärgede osas tõin doktoritöös välja, et rahvusvahelise kommertsialiseerimise institutsionaliseerimine oli vähem nähtav väiksemates ülikoolides ja innovatsiooni-põhistes sektorites (Artikkel I). Lepingulise koostöö ja koostööprojektide puhul oli see ka väiksemate ülikoolide puhul strateegiliseks eesmärgiks ja nad olid välja töötanud vastavad reeglid, loonud struktuurid ja kujundanud praktikad (artikkel II).

Minu doktoritöö panustas rahvusvahelise ülikooli ja ettevõtete teadmussiirde alastesse uuringutesse ka empiiriliselt, lisades sinna Eesti kui areneva majanduse konteksti (artikkel II) võrdluses rohkem arenenud riikidega (artikkel I, artikkel III). Eesti on huvitav uurimisobjekt, arvestades suhteliselt lühiajalist turumajanduse perioodi ja ettevõtete vajadust investeerida organisatsiooni tasandi õppimisse. Nii Eestit kui siin paiknevaid ülikoole iseloomustab väiksus, mistõttu erinevalt arenenud riikidest ei ole ülikoolide tehnoloogiasiirde keskused rahvusvahelises teadmussiirdes juhtivaks osapooleks ja rahvusvaheline kommertsialiseerimine on võrreldes teiste teadmussiirde kanalitega vähem oluline.

Doktoritöö juhtimisalane ja praktiline panus seisnes selles, et doktoritöös rõhutati teadmussiirde laiemat iseloomu kui turupõhised suhted, mida juhib ülikooli tehnoloogiasiirde keskus (artikkel I). Teadmussiire vajab ka teiste osapoolte panust nagu teadlased ja teadmust kasutavad ettevõtted, seda eriti väikemate ülikoolide puhul. Selleks on vajalik teadlaste ettevõtlusega seotud teadmiste ja oskuste arendamine. Ja võrgustiku loomine ettevõtetega, et kaasata neid ülikoolis loodud tehnoloogiate kommertsialiseerimise potentsiaali hindamisse. Lisaks, kuigi suur osa teadmussiirdest toimub suurte vahemaade tagant, aitab (ajutine) geograafiline lähedus sellele kaasa (artikkel II). Väikeriigi kontekstis on vähese T&A tegevuse kogemusega ettevõtetel piiratud võimalused rahvusvaheliste teadmusvõrgustikega liitumiseks ning partnerlus kohalike ülikoolidega on üks võimalik lahendus (artikkel III).

Appendix

Publication I

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How to commercialise university-generated knowledge internationally? A comparative analysis of contingent institutional conditions

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ABSTRACT

Our paper sets out to explore the contingent institutional conditions that underpin knowledge transfer, and particularly commercialisation, from universities to enterprises across national borders. We explore the phenomenon in four technology-focused and research leading (in the national context) universities in Estonia, India, Portugal and the UK. We argue that participants in interactions (despite the fact that they maintain their core operations in different institutional fields) possess common knowledge bases, and shared norms and cognitive frameworks. In many cases however, the emergence of organisational rules to facilitate interactions do not lead to the institutionalisation of the processes at work: restricting the scope of both existing interactions and their advancement and offering a central role to nonpracticing entities. The paper advances university-led pooling of intellectual property (geographically or sectorally) as an alternative for institutionalisation.

1. Introduction

The central locus of innovation has become increasingly international and dependent upon linkages between different types of organisations and sources of knowledge (Heitor, 2015). This is partly because of the offshoring of corporate R & D facilities (Karlsson et al., 2006), leading to increased international technological collaborations often as part of global innovation networks (Gassler and Nones, 2008; Li, 2010). These are enabled by the low cost and global proliferation of ICTs that enable more distributed innovation processes (Schwaag Serger and Wise, 2010). At the same time, universities, viewed as sources of competitive edge that can advance innovation through the commercialisation of knowledge generated by the academic community (Wilson, 2012), are increasingly globally-engaged: through rapidly growing numbers of international co-publications, cross-border patenting, and human (scientific) capital mobility (OECD, 2008).

The exploitation of opportunities that come from the international transfer of university-generated knowledge requires participants, i.e. universities and enterprises, to interact effectively outside the institutional terrain (the terms that will be used hereafter is field) of their core operations, education and research in the case of the former and business venturing in the case of the latter. More specifically participants must interact in institutional fields differentiated by: i) type of organisation that tend to give rise to differences in goals, interests and time horizons informing R & D behaviour of participants in the interaction (Siegel et al., 2003), and ii) country, which influences prevailing regulatory regimes, and a broad range of cultural characteristics (language, religion and other) (Ionascu et al., 2004: 4). Interacting across fields is influenced by sectoral characteristics (as will be discussed in more detail in the following Section): as the effects of between-country institutional differences may vary on account of sector specificities, whilst between-types-of-organisation differences may be shaped by sectoral systems (Malerba, 2005).

The underlying assumption of existing literature is that interacting across institutional fields is important in influencing the incidence and direction of international knowledge transfer (Malik, 2013). Institutions provide boundaries to the interactions, and influence (or according to some scholars determine) choices: facilitating more frequent interaction between participants in the field than with those outside (Scott, 1995). The challenge of interacting across fields may be persistent as institutions are path-dependent, as a result of their evolution in historical time in distinct organisational, sectoral and country contexts (Hodgson, 1988). Thus, in the main, interacting across institutional fields,[1] in the case of our paper transferring university-generated knowledge

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[1] The institutional field is a key concept used in our paper. It is defined as 'a community of organisations that partakes of a common meaning system, and whose participants interact more frequently with one another than with actors outside the field' (Scott, 1995, p. 56).

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internationally, may be less frequent even if opportunities exist in bridging such fields (Burt, 2004). Within this intellectual context our paper sets out to *explore the contingent institutional conditions that could foster the international transfer of university-generated knowledge, and particularly commercialisation, to enterprises*.

The importance of the institutional context (organisational, sectoral and country) prompted us to adopt a comparative approach. Thus, we focus on four national contexts: the UK, Portugal, Estonia and India that vary considerably in terms of historical trajectories, embeddedness of intellectual property (hereafter IP) relating regulation, and knowledge generating capabilities (discussed in more detail in the third Section of the paper). Within each national context we selected one university: focusing on those that possess strong knowledge generating capabilities, and are viewed as leading (nationally) in knowledge transfer (hereafter KT). In each of these organisational contexts we identified two cases of international commercialisation. Deciphering these cases placed emphasis not only at national and organisational institutional factors but also at the implications of sectoral systems (using influences particularly pertinent for the purposes of our study, such as the type of knowledge involved).

The rest of our paper is organised as follows. The next Section engages with the literature on university-industry KT and institutional theoretical constructs. Then we proceed to explain the design of the study, data collection, the analysis processes deployed, and limitations. The fourth Section compares the eight cases of international interaction with enterprises, whilst Section 5 focuses squarely on the analysis of institutional factors. The penultimate Section discusses our findings and develops propositions. Finally, the paper presents some final conclusions and explores implications for future research.

2. The literature

2.1. The internationalisation of knowledge transfer in context

In order to understand the nature of the transfers involved and position our research in the existing body of literature we decided to advance a typology of KT internationalisation. This combines two criteria: i) the nature of the knowledge transfer activity with that of ii) the type of internationalisation. The former draws on the ideas of Perkmann et al. (2013) who advanced an increasingly influential divide between academic engagement and commercialisation. It includes 'formal activities such as collaborative research, contract research and consulting, as well as informal activities like providing ad hoc advice and networking with practitioners' (Perkmann et al., 2013: 424). Commercialisation is defined in this context as 'the patenting and licensing of inventions as well as academic entrepreneurship' (Perkmann et al., 2013: 423). This divide is also reflected upon the degree of the user (i.e. the enterprise) involvement in the process of knowledge generation. Thus, commercialisation revolves around knowledge generated from research that is academically driven, publicly funded, and subsequently owned by the University. The second criterion draws from Jin et al. (2011) who distinguish between i) direct linkages between universities and enterprises operating in different national settings, and ii) indirect ones (for example relationships with (invariably) a multinational through its domestic subsidiary, or those established with foreign companies through universities operating in the same (as the knowledge user) national context. Our paper focuses on the top right-hand corner of Table 1: exploring direct international commercialisation. This invariably involve the development of a new relationship, touching upon a novel area of research in institutional theory as will be discussed in the sub-Section below, as the enterprise is usually not involved in the generation of knowledge.

2.2. Institutional theory

The type of interaction explored in our paper is of particular interest conceptually for institutional theory: on account of a gradual shift in emphasis from within to between institutional settings. More specifically, this stream of institutionalist thinking poses the question: 'how social choices are shaped, mediated and channeled by the institutional environment' (Wooten and Hoffman, 2008: 130)? Thus, action is not defined by the actor but influenced (or even determined) by a perspective that is common to a group of participants in the interaction. Analysis focuses overwhelmingly within an institutional field. This emphasis on the integrity (though not necessarily the boundaries) of the field underpinned the charge that it over-emphasises homogeneity of the actors involved in specific institutional fields (Wooten and Hoffman, 2008). This, in turn, is viewed as leading to a form of 'institutional determinism': where actors act out institutionally prescribed actions leading to stability and inertia.

More recently however, there is increased acknowledgment of situations where individuals from different institutional fields interact. This constitutes a shift in emphasis away from actors who occupy positions that bridge different fields, enjoy exposure to the institutions that characterise the different fields, are able to distance themselves from these and 'transpose', 'transplant' and 'recombine' institutions across fields (Sahlin and Wedlin, 2008). Instead research focused increasingly on interactions taking place in the boundaries of institutional fields. Boundary work involves creating, expanding, reinforcing, blurring, opening and crossing social boundaries between fields across time, space and levels (Helfen, 2015). The outcome may be the reproduction of the field or the introduction of change in institutions (Gawer and Phillips, 2013). More recently, research focused on interstitial spaces, i.e. 'small-scale settings where individuals positioned in different fields interact occasionally and informally around common activities to which they devote limited time' (Furnari, 2014: 440), exploring the initial emergence of new practices that may eventually become institutionalised. Our inquiry focuses on interactions that, like boundary work and interstitial spaces, take place between institutional fields, thus, involving no common/shared institutional basis. In fact, participants maintain their core activities in different institutional fields: namely market ones in the case of enterprises and open science in universities. However, and unlike boundary work, these interactions are developed 'de novo' (as shown in Table 1). These interactions differ from interstitial places in that they are invariably formal (involving contractual arrangements between participants).

Existing research on the contingent institutional factors that underpin the transfer of university-generated knowledge in general (Bjerregaard, 2010; Hsu et al., 2015), and particularly internationally (Malik, 2013), has remained relatively detached from these debates, with the exception of Taheri and van Geenhuizen (2016). Probably the most coherent treatise of institutional factors is that of Bjerregaard (2010): who draws from Scott's conceptualisation of institutions. This paper follows on this tradition as it allows for the exploration of institutions from the extremely fine grained (i.e. within one organisation) to broad grained (i.e. nationally or even transnationally). Thus, we tapped into the ideas of Scott who distinguished between 'cultural-cognitive, normative and regulative elements that, together with associated activities and resources, provide stability and meaning to social life' (Scott, 1995: 33). Regulative elements emphasise rule setting and sanctioning, whilst normative elements contain an evaluative and obligatory dimension. Lastly, cultural/cognitive factors involve shared conceptions and frames through which meaning is understood (Powell, 2007). These three elements form a continuum moving 'from the conscious to the unconscious from the legally enforced to the taken for granted' (Hoffman, 1997: 36). In the following sub-Section we will try to disaggregate institutional factors further: combining insights from institutional theory (in the tradition of Scott) and empirical evidence from the KT literature.

Table 1
Types and means of international KT coordination.

	Academic engagement	Commercialisation
Direct international linkage	Enterprise located internationally that participated in the production of the research outcome engages in its exploitation.	Enterprise located internationally develops a new relationship in order to access university generated and owned knowledge that is the result of curiosity driven research.
Indirect international linkage	Enterprise located internationally that participated through a subsidiary or national university in the production and the exploitation of research outcomes.	Enterprise located internationally develops through a subsidiary a new relationship in order to access university generated and owned knowledge that is the result of curiosity driven research

2.3. Institutional factors

Regulations are established at different levels and shape behaviours through their provisions, inspection of conformity with the rules and the imposition of the sanctions and rewards involved (Scott, 2013). They are not merely means of restricting behaviour, but also enabling and incentivising actors as well as establishing certainties (for example through the conferment of rights) that may facilitate interaction. The logic that drives the development of a regulation is an instrumental one: individuals develop the rule they believe that will advance their interests, and comply with it in order to reap rewards and avoid sanctions. Institutional theorists acknowledge the importance of macro-level regulations as manifested in law and implemented in courts, professional statutes, and prerogative of public agencies (DiMaggio, 1988). However, there is also recognition of procedures created within organisations, in part to conform with macro-level regulations but also in order to institutionalise existing practices that are viewed as important in attaining success (DiMaggio, 1988). Thus, we will distinguish here between regulative institutional influences originating from national regulation and organisational rules and procedures.

There is a voluminous body of literature exploring regulations at different levels in university-industry KT in general and commercialisation in particular. At the national level, this goes back to the introduction of Bayh-Dole Act that 'allowed universities to own the patents arising from federal research grants' (Grimaldi et al., 2011: 1046). These regulations governing the ownership of university-generated research outcomes underpinned an emerging consensus of academic opinion regarding a move away from 'open science' rules to a 'model, where the identification, protection and exploitation of intellectual property is central (Murray and Stern, 2007). However, there is also recognition in the accumulated literature of the differential effect of national rules in specific sectoral systems. In an influential contribution, Malerba (2005) illustrates the importance of strong patent protection in chemicals, influencing the architecture of the sector, whereas in software the centrality of IPRs has been greatly affected by the open source movement. In the latter context, standards (and their development and the actors involved in the process) play an increasingly important role.

There is also research into the development of rules at the organisational level, particularly from the point of view of knowledge providing organisations, regarding commercialisation. This research revolves around the proliferation of technology transfer offices (Phan and Siegel, 2006) and the associated set of rules and implementation mechanisms encouraging disclosure and academic entrepreneurship (Grimaldi et al., 2011). Of particular relevance is the development of rules that incentivise academics not only to disclose but also to lead IP exploitation, and the internalisation of these regulations by academics (Bjerregaard, 2010). More recently, there has been increased emphasis placed on the role of organisations that provide a rule-governed context for interactions: nonpracticing entities (defined as organisations that own and often assert IPRs but do not practice, in the sense of directly exploiting, the knowledge covered by the IPRs (Meurer and Bessen, 2014)). They generate or (more often) acquire protected knowledge with the aim of securing licensing income through commercialisation. Advocates of nonpracticing entities view them as potentially efficient middlemen, connecting those who invent but whose inventions have not been deployed (such as universities) with those who can produce an innovation from that invention (Spulber, 2012). Critics argue that they discourage innovation by generating excessive social costs through frivolous litigation (Meurer and Bessen, 2014). Organisational rules are influenced at least in part by sectoral systems. For example, in engineering the nature of the knowledge involved means that early Technology Transfer Officer (hereafter TTO) engagement with enterprises is important: underpinning the development of rules to facilitate this (Mosey and Wright, 2007). Instead, the knowledge involved in biological sciences, necessitates early involvement of equity investors though the advancement of institutionalised solutions: university managed equity funds (Croce et al., 2014).

Normative institutions introduce a prescriptive and obligatory dimension in actor behaviour. Thus, they identify the appropriate goals and actions that can be pursued by actors occupying specific positions within a field. They underpin expectations that other actors hold about the behaviours linked with a specific position and may become internalised (Scott, 2013). Like regulations they are also restricting and enabling. The central logic of normative institutions is appropriateness: i.e. 'given the situation and my position within it what is the appropriate behaviour for me to carry out?' Existing research distinguishes into two types of norm: descriptive and injunctive (Cialdini et al., 1990). The former informs individuals of what is being done within an institutional field. It describes the prevalence of a certain behaviour and thus encourages the adoption of that behaviour since prevalence implies usefulness in managing social life. Injunctive norms are related to the evaluation, by those within the institutional field, of a certain behaviour. It involves approval or disapproval, and functions as pressure on an individual to perform or not perform a behaviour.

The bulk of research on university-industry KT in general and commercialisation in particular focuses upon injunctive norms. More specifically, in the case of knowledge providers at the organisational level research norms are viewed as central: thus, aligning KT activities (and commercialisation in particular) with research (through generating revenue and ease funding pressures on research) (Welsh et al., 2008). At the individual level, academics that occupy the knowledge provider position subscribe to traditional and scientific norms (Perkmann et al., 2013). Diverse manifestations of this are apparent in career-progression (Lam, 2007), the importance attached to non-monetary objectives (Azagra-Caro et al., 2008). There is some evidence that doing so impacts adversely on involvement in commercialisation (Krabel and Mueller, 2009). Interestingly, however, academics may also occupy a position as knowledge users (bridging fields) in instances where they lead or are involved in spin-off activity. This position necessitates the adoption of norms associated with the entrepreneurial act opening up the scope for incongruity and conflict with traditional scientific norms (Perkmann et al., 2013). Enterprises, in the literature, use knowledge generated in universities in order to secure financial gain (Siegel et al., 2003).

There is much less research exploring normative descriptive institutions in KT and commercialisation. Within universities there is evidence that academics are more likely to engage in commercialisation activities if departmental colleagues of the same rank adopt this type of

behaviour (Bercovitz and Feldman, 2008). This argument is placed somewhat differently by Jain et al. (2009) who emphasise the importance of increased awareness, amongst academics, of commercialisation possibilities and actual involvement in this. From the point of view of both universities and enterprises Bjerregaard (2010) stresses the importance of a shared cultural micro-cosmos for collaboration. He goes on to argue that interaction may also facilitate a process of enterprise 'scientification' involving the adoption of 'open science' norms.

Existing institutional theory research places particular emphasis on cognitive-cultural institutional influences (such as language, religious and ideological ways of understanding the world and others). This is because pre-established cognitive frameworks (viewed here as an element of cognitive institutions), at least in the beginning, influence sharing of knowledge and learning process (Nooteboom et al., 2007). Differences in cognitive frameworks may cause misunderstandings and conflict between participants (Inkpen and Tsang, 2005), and in that situation they may decide to restrict information exchange affecting negatively outcomes (Krause et al., 2007).

Research into KT and commercialisation appears to overlook the significance (or not as the case may be) of cognitive-cultural institutional differences. Thus, in this paper this will be captured in terms of the language used by participants, as identified by Malik (2013) in a exploring international KT and its cognitive frameworks. Another dimension of cognition that is particularly relevant for KT in general and commercialisation in particular, revolves around common knowledge bases (Lane and Lubatkin, 1998). Operationally this may be examined in terms of the commonality of patents owned by participants in the interaction. Knowledge bases are formed of mental models which are representation of the world that are shaped through interaction with other people and surroundings and used to control the world through making sense and anticipating events (Jonson-Laired, 1983). The argument goes that cognitive knowledge bases should be similar enough in order to communicate, understand and process scientific knowledge successfully but too much cognitive proximity have negative effects (Nooteboom, 2000). Hewitt-Dundas (2013) suggests that the transfer of university-generated knowledge is facilitated when enterprises have internal R & D capabilities. This view is moderated by Xu et al. (2011) who identify a differential effect between foreign owned and locally owned ones.

Sectoral systems are particularly important influences of knowledge bases. This is because the very nature of the knowledge involved in the transfer may vary considerably: with profound implications on institutions governing its transfer. For example in the case of the biotechnology industry the (scientific) knowledge involved is both abstract and codifiable making it relatively easy to protect through patents (Saviotti, 1998). In contrast, in sectors such as software where the knowledge involved is often tacit (as it is linked with a complex and diversified base) impacting adversely on the importance of IPRs such as patents (Aramand, 2008). Thus, sectoral systems impact upon cognitive institutional conditions influencing the commercialisation of university-generated knowledge internationally.

3. Methods

3.1. Research design

The study was designed as comparative case research. This is because it allows for the exploration of a phenomenon (international commercialisation) within its real life context and comparison of findings across different cases (Yin, 2003). The national contexts selected were identified for their diversity in two important sets of factors, as suggested by Audretsch et al. (2014). Firstly, there was profound diversity in terms of institutional development: from advanced market (UK), to post-socialist (Estonia) and emerging (India) – as captured in Table 2. For example, the degree of protection of IPR varied profoundly between the UK, occupying the eighth position globally, and India, who is placed 71st. Similarly, there were significant differences in the degree to which institutions underpinned close collaboration between universities and industry: with the UK being 8th and India 47th. Secondly, there were considerable disparities in the knowledge generating capabilities of the four countries examined here: ranging from one of the leading globally (UK), to an emerging leader (India), a medium-sized knowledge producer (Portugal), and a relatively small one (Estonia). However, on the measure of per scientist publications (to adjust for size) there are only modest differences in the position of countries, with Estonia (surprisingly) being best placed (Table 2).

Table 2
The National Research, Development & Innovation Context, 2013 (rank order).

	Estonia	India	Portugal	UK
Number of publications[a]	62	7	26	3
Number of publications per scientist[a]	25	36	31	27
University-industry linkages[b,c]	36	47	27	5
Intellectual property rights[b,d]	31	71	38	8

[a] Scopus.
[b] World Economic Forum.
[c] Indicator capturing the degree to which businesses and universities collaborate on R & D (enterprise survey data).
[d] Indicator capturing the degree of protection of IPRs (enterprise survey data).

Table 3
Description of university and its commercialisation activities in 2013.

	IIT Delhi	TUT	UoLis	UoMan
Research outputs[d] (rank order nationally/total nationally)[a]	4/209	2/5	1/34	4/184
Innovative knowledge[e] (rank order nationally/total nationally)[a]	3/209	2/5	1/34	4/184
Science & technology based faculties/ total faculties[b]	11 out of 13	6 out of 8	9 out of 18	3 out of 4
Number of academics[b]	485	1155	3461	4555
Number of publications[c]	1066	308	2565	4619
Number of citations[c,f]	2240	867	6691	29,869
Citations per paper[c]	2.1	2.8	2.61	6.5
H-Index[c]	14	11	23	53
Total number of patents held[c]	103	34	139	513

[a] Scimago.
[b] University own data.
[c] Scopus.
[d] Total number of documents published in scholarly journals indexed in Scopus.
[e] Scientific publication output from an institution cited in patents.
[f] Citations in 2013–2014.

In order to identify instances of the phenomenon (international knowledge commercialisation) it was important to select organisational contexts that have a technological orientation, possess strong knowledge generating capabilities, and are viewed as leading in KT within their respective and profoundly different, as described in the next Section, national contexts. We selected the Indian Institute of Technology Delhi (IIT Delhi), Tallinn University of Technology (hereafter TUT), the University of Lisbon, and the University of Manchester. Table 3 provides an illustration of the technology focus of the key units of the Universities (Faculties) and international comparable data provided by SCImago.[2] The latter shows on two measures the very strong national position of the universities selected: i) research outputs, i.e. the rank position of the institution nationally in terms of papers published in scholarly journals indexed in SCOPUS, and ii) innovative knowledge,

[2] The choice of an international dataset was primarily for practical purposes: as it provided already comparable data. It is worth pointing out here that the data are weighted for size of institutions.

namely rank position of the institution nationally in terms of number of scientific publications from the institution cited in patents.

However, despite the common technological focus and the leading position occupied by the four organisational contexts selected, there were differences in their shape and size reflecting disparities in the national context and distinct historical organisational trajectories (Table 3). Knowledge production capabilities vary considerably between the universities concerned. In 2013 academics working at the University of Manchester produced more than 4500 papers, which have been cited around 30,000 times in the following two years. The corresponding figures for the University of Lisbon were 2500 and more than 6600 respectively. However, in IIT Delhi there were just over 1000 journal papers and 2200 citations. Lastly, in TUT more than 300 papers were published in 2013, which were cited more than 800 times in the following years. The exploitation of knowledge generated by these universities is captured in terms of new patents granted. The University of Manchester stands out as it had a portfolio of some 513 patents in 2013. IIT Delhi and University of Lisbon had a portfolio of 103 and 139 respectively, whilst TUT held just 34 patents.

In order to capture the effects of sectoral systems we drew upon a relatively well-established divide from the existing body of literature (Asheim and Gertler, 2005; Malerba, 2005; Salavisa et al., 2012) that is relevant for the purposes of our study revolving around the type of knowledge involved and the relative position of universities in the processes at work. The first sectoral system involves science-based knowledge: i.e. it is driven by discoveries in universities based on deductive processes and formal models and appeals to abstract "know-why". Within this context, there is proximity between scientific principles and application, easy codification (thus IPRs are of considerable importance), and scope for exploitation across a wide range of industries (Salavisa et al., 2012). Examples of science-driven sectoral systems include biotechnology, pharmaceuticals and chemicals. The second sectoral system involves knowledge often, but not solely, generated for the purposes of introducing innovation, thus, knowledge creation arises from specific problem solving through inductive processes of testing and experimentation. In this system tacit knowledge is of greater importance (undermining the centrality of patents and other forms of individual protection of intellectual property), whilst the knowledge is often applicable in a rather narrow sectoral setting. Exemplars of innovation-driven sectoral systems include software and electronics.

3.2. Data collection and analysis

The cases of international knowledge commercialisation were identified based on information received from well-informed individuals, mainly TTOs and university managers at each university. In our selection, we tried to include cases across sectoral systems, demonstrating a broad range of processes, i.e. licensing, spin-off and others, and very importantly instances of both success and failure (though the latter were more difficult to trace). Data richness was also an important consideration. Overall, nineteen such instances were identified in the four case study contexts: with eight of these selected (two from each University).

Primary data was collected from actors that were involved in knowledge commercialisation from different perspectives. Thus, we conducted a total of 47 interviews with five stakeholder groups: senior university managers (eight interviews), academics (sixteen), TTOs (nine), entrepreneurs (eight) and government officials (six). In terms of geography there were ten interviews conducted in Estonia, twelve in India, thirteen in Portugal and twelve in UK. Interviewees were selected through non-random purposeful sampling including criterion sampling and snowball sampling (Patton, 2002). There were two-stages in interview data collection. The first involved individuals with oversight of the process and direct involvement in the development of policies and practices supporting commercialisation (such as senior academic leaders, TTOs, etc.): they provided context and identified instances of the internationalisation of commercialisation. Secondly, there were academics and entrepreneurs that had been directly involved in the commercialisation of IP. The interview schedules consisted of four main sections of questions: knowledge production, KT (including international activities), actors and relationships, governance and management of KT. The interview schedule was similar for the five target groups with slight variations depending on the interviewee's profile. For example, in the case of government officials, emphasis was placed on the issues of governance and managing KT. The academics and entrepreneurs, on the other hand, were asked to describe more thoroughly their own experiences of international KT in the area of commercialisation of IP. The interviews were carried out in 2014 and lasted between one and one and a half hour each. In most cases the interviews were recorded and transcribed; in case the interviewee viewed the context as too sensitive notes were made of the interview.

In order to construct the case studies and particularly to capture institutional factors influencing international knowledge commercialisation secondary data sources were also used. These included national and university regulations, R & D reports, company web-pages, press-releases, and others. These sources of data covered: i) the context of commercialisation, such as national Research, Development and Innovation policy documents and analysis, university KT regulations, university R & D reports, and ii) case-specific ones: namely web-pages of enterprises, press-releases regarding commercialisation of IP, and information in databases (Scopus, Espacenet patent search).

The analysis of interview and documentary data consisted of a series of steps (with the help of 'peer debriefing'), searching for within-case similarities coupled with cross-case differences or in other words "the simplicity of the overall perspective" (Eisenhardt, 1989, p. 547). Each of these cases offers an opportunity to learn and integrates context analytically into the explanation rather than simply using context (as a description) to enhance understanding (Welch et al., 2011). As a first step, we thus used directed content analysis and coded the interview script data in terms of key themes identified in the literature in the previous Section (Hsieh and Shannon, 2005). In doing so, we used role-ordered matrices to compare views coming from different groups of interviewees (academics, entrepreneurs, TTOs and others), for each institutional pillar and factor. In a second step, we purposefully looked for patterns across cases, and collapsed the previous themes into two overarching ones. These were: cross-scale institutional factors and processes at work that result in successful commercialisation of IP (Miles et al., 2014). This led to a final reordering of the case study data that focused on institutional factors not only across pillars but also between actors within each pillar (underpinning success or failure).

3.3. Limitations

There are some apparent limitations in our research, linked with our data collection methods. Specifically, we focused on the same type of university context (technology-focused, leading research and KT), thus, we are unable to undertake comparisons between different types of university. Our findings may have been different if we have examined cases of knowledge user organisations: and country implications upon them. Lastly, and despite our efforts to explore cases of both success and failure, we identified a single instance of failure on account of institutional factors. Linked to this, we had to restrict ourselves on instances where an interaction was established: and we were not able to examine interactions that floundered in the very early stages of the process.

4. The case contexts

The cases involved in this study are presented in Table 4. Half of these (Gamma, Zeta, Eta and Theta) were in a science-driven sectoral system, whilst the other half in an innovation-driven one. The other participant in the interactions is in most, but not all cases, a potential

Table 4
Overview of cases of direct internationalisation of commercialisation.

Case	HEI	Partner	Sectoral system	Process	Mechanism	Outcome
Alpha	TUT	Finnish user-enterprise (SME)	Innovation driven	The enterprise sought technology complementing its own (own patents pursued simultaneously). Approached TUT after searching 'research markets', using academic networks (the SME being an academic spin-off itself) to establish contact. Licensing negotiations included the university (TTO), the academic-inventor and the representative of the enterprise and followed a standardised process: including concluding non-disclosure agreement, approving the business plan, etc.	Licensing	Signing of licensing agreement; receipt of royalties
Beta	TUT (spin-off)	UK nonpracticing entity	Innovation driven	An intermediary-enterprise originating in the UK approached a spin-off from TUT, holding university IP, with the aim of investing in return for equity. Prolonged negotiations did not produce agreement as the owners of the spin-off did not want to lose majority ownership.	Strategic partnership	Break-up of interaction
Gamma	IIT Delhi	User-enterprises in the UK, USA and Australia	Science driven	Professors and students set up company to commercialise the IP generated. The company, building on the reputation of the researchers and alumni linkages, sought investment from venture capitalists and angel investors. Cambridge University's Ignite programme helped it form partnerships with pharmaceutical firms (one owned by IIT alumni) in US and UK.	Licensing	Signing of confidentiality agreement.
Delta	IIT Delhi	US nonpracticing entity Singapore subsidiary	Innovation driven	The Singapore based subsidiary office of a US intermediary enterprise that had memorandums of understanding with other IITs identified the potential technology available IIT Delhi and approach the technology transfer office (FITT). The MNC agreed to pay the license fee and bear the patenting cost associated with this invention. A US patent was filed.	Strategic partnership	Signing of agreement; receipt of royalties
Epsilon	UoL (spin-off)	United Kingdom and Spain user-enterprises (SMEs)	Innovation driven	The spin-off company is internationalised through sourcing of production and FDI. The internationalisation was a goal since the start-up and the company exported in its first year. The sourcing of production to a European and Asian country was not intentional but a necessity, since they have not found a Portuguese company interested in producing the product components.	FDI, outsourcing of production, establishing affiliates abroad	Establishment of affiliates.
Zeta	UoL	User-enterprise based in the UK (MNC)	Science driven	Multinational company pursued the potential of an invention (patented) created by academics. The academics consider that the effective protection of the university IP depends of it licensing to a large company that can register it worldwide and enforce the property rights. Negotiations to license the technology have begun and, at the same time, the enterprise funded a project so that the inventors could develop the technology further, since they had the relevant knowledge to do it.	Licensing of IP	Licensing process interrupted due to change in market positioning of the enterprise
Eta	UoM	US user-enterprise (MNC)	Science driven	The University of Manchester benefited from the transfer of a research team (and IP) from a UK based company (2007). University and research council funding led to the generation of new IP. UMIP, as part of its commercialisation activities, promoted this IP in the United States and was successful in establishing a licensing agreement with the company. The aim of this is to use IP in order to develop a new compound for the treatment of skin diseases.	Licensing of IP	Licensing agreement; pre-clinical trials; US company changed priorities away from this invention.
Theta	UoM	US based user-enterprise (SME)	Science driven	The University of Manchester is recognised as a global leader in the development of a new material. It established a strategic partnership with one US-based enterprise leading commercialisation of material. This involved the location of the European headquarters and production facilities of the enterprise in Manchester, joint development work (using material supplied by the company) and support for the commercialisation of the IP generated by the University.	Strategic partnership	Opening of European basis of company at Manchester.

user-enterprise. Indeed, in two cases (Beta and Delta – both revolving around innovation-driven sectoral systems) the participant is what could be best described as a nonpracticing entity: accessing university owned knowledge with the aim of generating licensing income through its diffusion to user-enterprises. The nonpracticing entity involved in the case of Delta: has been successful in pooling tens of thousands of patents from universities and private inventors across the world. The nonpracticing entity involved in Beta tapped into university held IP primarily from post-socialist states (the Baltics, Poland, Russia, Ukraine) and China.

The divide between user-enterprise and nonpracticing entities influences both the knowledge bases involved (as will be discussed below) as well the mechanisms used. In the case of the latter this takes the form of a strategic partnership regarding the exploitation of the IP, whereas in the case of the former mostly of a direct licensing agreement or spin-off: only in one case (Theta) involving a strategic partnership.

There are considerable disparities regarding the participant driving the interactions. In a number of instances this is the enterprise (user or nonpracticing) that aims to access the university owned knowledge: attracted by the research profile of individual academics (Alpha, Beta, Delta, Zeta). In other instances (Gamma, Zeta) the academic-inventor him or herself is pursuing the establishment of an international interaction. Interestingly, it is only in two cases (Eta and Theta) that the university is directly and proactively pursuing linkages with user-enterprises respectively located across national boundaries. As stated previously, the study pursued the inclusions of cases of both success and failure. Three cases can be characterised as a failure, one in Estonia (Beta), one in Portugal (Zeta) and one in the UK (Eta). Failure was manifested in different ways: break-up of the interaction, interruption of the pursuit of licensing, or withdrawal from the agreement. In one case (Beta) the reasons for failure revolve around the institutional dimension, and will be examined in more detail in the Section below. In the cases of Zeta and Eta outcomes fell short of initial participant expectations because of a change in the priorities of the multinational corporation (hereafter MNC) in the former case and poor results of early testing in the latter. These two cases constitute apt reminders that non-institutional factors may also be important in determining of the processes and the outcomes of international commercialisation of university-generated knowledge.

5. Analysis of institutional factors

5.1. Regulatory

Not unexpectedly, the geography of the interactions (Table 4) shows that university-generated knowledge is accessed from (when the process is driven by the enterprise) or diffused towards (when led by the university) settings that possess strong IP protection and enforcement. More specifically, users of knowledge are located in Finland, Singapore, UK, and the USA: occupying positions one, two, eight and twenty respectively on the same IPR protection measure used in Table 2. This indicates that interactions are established when there is strong protection of IPR in the setting of the enterprise, irrespective of the fact that protection in the country where the university is located is modest or relatively weak.

At the organisational level, there is differential advancement of regulation governing international commercialisation. Indeed, in all four university settings there are rules governing such interactions. In the case of TUT and the University of Lisbon these rules are operationalised through autonomous departments (Innovation and Business Centre Mektory and the Projects, Entrepreneurship and Knowledge Transfer Office respectively) within the organisation. Moreover, in these settings international commercialisation is not pursued pro-actively. The small patent portfolio and the absence of patent families in TUT prevent the institutionalisation of practices that would facilitate international commercialisation: as articulated by the university's TTO who explained that 'so far the solution is researcher himself … the researcher has more contacts than all others and is more likely to find a buyer for its invention.' (TUT_TTO1). This is also the case in Portugal, where the internationalisation of the knowledge transfer has not yet been put in the priorities of the TTO. In the context of IIT Delhi and the University of Manchester organisational rules exist in the form of distinct wholly-owned university subsidiaries: the Foundation for Innovation and Technology Transfer (FITT) and University of Manchester Intellectual Property (UMIP). However, it is only in the case of the University of Manchester where there is explicit intend to 'be recognised internationally for the excellent quality, significant scale and the distinctiveness of [its] … work in the successful commercialisation of appropriate research … outputs' (UMIP, 2010, p. 10). This underpinned the identification of transnational IP income flows, and established rules for the advancement of institutionalised linkages particularly with intermediary and user enterprises in the US, and to a lesser degree the EU, as key priorities, that underpinned 'a straightforward dialogue with prospective investors' (UoM_TTO1). Evidence of their importance is shown in the case of Theta, and to some degree Eta.

Similarly, there was differential advancement of organisational rules amongst the enterprises involved in the interactions. In the cases of the nonpracticing entities involved in Beta and Delta: these were well developed as they underpinned their core operations: i.e. to 'be one of the leading players globally in international IP commercialisation … through the world's largest international network of universities and research institutions' (TUT_E1). In these cases the volume of interactions involved meant that there was an institutionalisation of the processes at work. Developed organisational rules were also reported by enterprises' participants in the cases of Zeta, Eta and Theta (the former two being MNCs that often use university-generated knowledge in innovation). Organisational rules were less well developed in the remaining enterprise participants.

5.2. Normative

The prevalence of shared injunctive norms between knowledge producers and individuals in participant enterprises is an important influence in the success of commercialisation activities across national boundaries. Of particular importance, but not solely, are norms associated with what is widely understood as the 'science commons' (such as openness, community, mutual criticism and fair allocation of credit). For example, the senior academic from the University of Manchester involved in Eta stressed the importance of working with scientists within the knowledge using enterprise, but has also worked himself as Head of Research in the R & D facilities of a large multinational. Similarly, the chief executive officer of the US based enterprise involved in Theta has held a number of positions in public R & D facilities in his country of origin. The challenges of misalignment are apparent in Beta, where academics had to work with commercially driven knowledge users: 'we had negotiations … for half a year … but when we reviewed the conditions of an agreement they proposed we noticed we would be paying a huge salary for the general manager and financial manager that they have the right to appoint … My way of thinking is not too greedy, but working for pennies for people I do not know, is not what I want. The researcher is also a bit crazy, wants to do his own things.' (TUT_A8). This impacted directly on the failure of the interaction. This was also the case in Delta.

As far as shared normative descriptive institutions are concerned, individuals occupying different positions operate in environments where commercialisation activities are commonplace. More specifically, the departments where the academic-inventors work demonstrate considerable incidence of commercially exploitable knowledge. In the case of Alpha and Beta (both coming from the same academic unit) there were three patents granted between 2010 and 2013, six in the case of Eta and eight in the case of Theta. Moreover, users (at the individual scale) work in enterprises that have considerable experience of

engaging in commercialisation activities with universities. This may be linked to injunctive norms encouraging such activities, as shown in IIT-D where 'earlier good publications were one of the main criteria for your promotion … but now they give equal importance to how many patents you have filed and how much interaction you have with industries' (IITD_A2).

5.3. Cognitive

As identified in the literature, language constitutes an important cognitive influence. All eight cases examined here show linguistic alignment between participants in the interaction, re-iterating the commonly held view that 'the language of science is English'. Indeed, academics in these leading (nationally) universities, who have to publish internationally, are competent in the use of this medium of communication. This is also the case regarding individuals working in enterprises transacting externally and often internally (in the case of MNCs) in English.

Alignment is also apparent in the case of cognitive frameworks (captured here through the educational background of participants). This appears to be the case amongst the cases explored at the University of Manchester, for example in the case of Theta the CEO of the enterprise has been educated in a similar disciplinary setting as the academics that pioneered the knowledge output commercialised. Similar educational backgrounds are also apparent in all but two of the cases deciphered in this paper: for example in the case of Gamma from IIT Delhi stating that 'it is easier for the larger firms to interact with university as the firm representatives themselves are scientists' (IIT_TTO1). One case of difference is Epsilon: where the background of the persons involved in the spin-off was very different: cutting across scientific disciplines, namely engineering and management. This was seen as positive since it enabled complementarity. However, this case involved interactions around a fully-developed product, rather than knowledge that required advancement within the commercialisation process. Another instance of difference was that of Beta: between the academic and the investors (an instance where failure occurred).

In terms of common knowledge bases, in most of the cases examined in our paper the other participant in the interactions appears to possess patents in the same area where knowledge outputs are currently commercialised. For example in the case of Zeta the interaction between the academics and the MNC was facilitated by the deep technological knowledge the company had in the technology, expressed by a large portfolio of patents in that technological area. This was to a lesser extent also the case at Alpha, as the enterprise was in the processes of applying for legal protection of its own IP in parallel with the patent licensing process with TUT. In the cases of Beta and Delta there was no knowledge base held by the nonpracticing entities.

6. Discussion

Evidence presented in our paper advances incrementally three arguments previously articulated in the literature. Firstly, it shows that the emergence of IP protection and enforcement arrangements that transcend national boundaries (following the TRIPS agreement in 1994), provide the institutional basis for cross-border commercialisation activities: even in instances where interactions break down (Beta) or results fall short of expectations (Theta). IP protection and enforcement appears to be particularly important in the national setting of the enterprise rather than that of the university, as illustrated by the cases coming from IIT Delhi. Secondly, and potentially related with the previous point, the effective protection of the university-generated IP is a significant consideration particularly amongst cases in science-driven sectoral systems. Interestingly, this takes somewhat different manifestations: sought from the university commercialisation venture in the cases of Eta and Theta and externally in the case of Gamma and Zeta. Lastly, the widespread use of English in scientific pursuits also facilitates interactions even in the case of Estonia, with its historical linkages with Soviet (and Russian language using) science.

The findings of our research also point towards some novel insights in this empirical context. Specifically, whilst the actual interactions created in order to facilitate the international commercialisation of university-generated knowledge are new, their formation in some cases involves organisations (nonpracticing entities) that aim (as their core operation) to occupy the space between university and user-enterprise institutional fields. Their role is apparent in the cases of Beta and Delta, not surprisingly (on account of the more applicable nature of the knowledge involved) both revolving around innovation-driven sectoral systems. Whilst the involvement of nonpracticing entities does not ensure success, as shown in the former case, it is indicative of the innovation potential involved in the international commercialisation of university-generated knowledge.

Our findings point instead at a set of contingent institutional factors facilitating the international commercialisation of university-generated knowledge: common knowledge bases (organisationally) as well as injunctive and descriptive norms and cognitive frameworks (individually). Common knowledge bases are apparent in all but two of the cases (including those in science-driven sectoral systems where the knowledge transferred is codified) examined: Delta and Beta. Interestingly, the latter is a case where there was conflict and interaction break-up. Organisational knowledge bases, in turn, influence the scientific backgrounds of the individuals employed by participants in the interactions. Academics are employed by departments that are the repository of existing organisational knowledge. Similarly, researchers working in enterprises are concentrated in areas of past investment or future growth areas. This leads, as shown by all but two of the eight cases examined in our paper to shared cognitive frameworks (captured in terms of educational background). Beta had a negative outcome, whilst in the case of Epsilon the actual product had already been developed and differences in cognitive frameworks did not have detrimental effects. Moreover, scientists, who work either as academics in universities or lab researchers in enterprises, have been trained in academe, have been influenced by science commons norms. Indeed, in some instances as shown in the case of Eta lab researchers in enterprises participated in the science commons, through publication, to a degree that underpinned a career move across fields. Lastly, academic-inventors worked in departments where the commercialisation of knowledge was commonplace, as shown by the incidence of patent activity. In fact, this poses the question (that merits further investigation) regarding the degree to which descriptive norms influence employment choices of academics, leading to concentrations of those capable of performing a more catalytic role in international commercialisation. Common knowledge bases, and shared norms and cognitive frameworks are the outcome of path-dependent trajectories: resulting from organisational decisions and investment and individual decisions about education and work experiences both unfolding through time. This underpins our paper's first proposition.

Proposition 1. New international commercialisation interactions are established between participants that possess, as a result of path-dependent trajectories, common organisational knowledge bases and shared individual (injunctive and descriptive) norms and cognitive frameworks.

The path-dependent nature of common knowledge bases and shared norms and cognitive frameworks means that they cannot be altered through action in the short- to medium-term. This restricts the scope for the development of new interactions only to those participants that meet the very specific institutional conditions described in Proposition 1. Moreover, the scope of existing interaction is very narrow: as it is invariably constructed around individual academic inventors (Alpha, Beta, Gamma, Epsilon, Zeta) and their knowledge generating capabilities, rather than those of a university as a whole. Thus, if an interaction fails (for example if the knowledge sought is bypassed as was

the case with Zeta) the investment by both participants is lost (as there is no wider residual link). It is the advancement of organisational rules and an institutionalised process of pursuing international commercialisation, as those identified in the interstitial spaces research that can widen the scope for the international commercialisation of university-generated knowledge.

Organisational rules aimed at facilitating commercialisation have been created in all university and enterprise contexts examined here. However, institutionalisation of the processes at work occurs only in some of the cases. Institutionalisation is apparent in two cases originating from the University of Manchester, where organisational rules are complemented by a declaration of intend (articulated though UMIP) to achieve excellence in commercialisation internationally, focusing on transnational income streams. More importantly, however, it is linked to the strongest (by some considerable margin) knowledge generating capabilities (in terms of papers), the most visible research outputs (as measured in terms of citations and research H-Indices), and the greatest volume of IP (in numbers of patents) amongst the four organisational contexts examined here. Institutionalisation, from the point of view of nonpracticing entities is also evident in the cases in Beta and Delta. The enterprises involved also combine rule governed settings for the institutionalisation of interactions, and scale by pooling the IP of a number of universities and private inventors. However, in both of these instances the pooling of IP is not achieved in the context of common knowledge bases and shared injunctive norms. This underpins the development of the paper's second proposition.

Proposition 2. The institutionalisation of international commercialisation, either in universities or enterprises, is the outcome of the combined effect of organisational rules, strategic intend, and the volume of the IP held by the organisation.

7. Conclusions

7.1. Concluding remarks

The point of departure of this paper was that the increased internationalisation of university-generated knowledge, facilitated through the global proliferation of ICTs and changing corporate R & D practices, can stimulate innovation in global networks and the advancement of solutions to global challenges (such as pollution, climate change, ageing population to name but a few). Our findings suggest that the realities of the national context and sectoral system, have some but only modest impact in shaping interactions. Instead, we argue that the ability of participants (both universities and user-enterprises) to engage in new interactions that cut across the boundaries of institutional fields, is primarily on account of commonality in a number of institutional factors (knowledge bases, norms and cognitive frameworks). This is novel theoretically as it illustrates that broad institutional field analysis may conceal more complex organisational institutional realities. Empirically, it is useful as it identifies a set of contingent institutional factors (Proposition 1) that underpin new international commercialisation interactions. Interestingly, these factors, like institutional fields, are path-dependent.

New organisational rules have been developed by both university and enterprise participants to facilitate interactions. In fact, nonpracticing entities emerged as an important rule governed setting, bridging institutional fields. They acquired relevance, by virtue of the size of their own IP portfolio, in instances where individual universities possess limited knowledge generating capabilities and modest volume of protected knowledge (Proposition 2). They were able to institutionalise the processes at work: in the case of the smallest university contexts and innovation-driven sectoral systems. This is in sharp contrast with university-led institutionalisation, in large knowledge producing universities and science-driven systems. More importantly, however, limitations on the facilitating capacities of nonpracticing entities revolve around their nature regarding the contingent institutional factors (own knowledge base, injunctive norms and cognitive frameworks) that underpin success.

7.2. Implications for practice and research

Our findings have implications for organisational practice and research. Regarding the former, we advance a potential solution to the challenge confronting universities possessing relatively modest, particularly if viewed globally, knowledge generating capabilities and volume of protected IP. This solution may take the form of a university-led organisation pooling university held IP either within defined geographical settings (for example a city, a region or small country like Estonia) or maintain research capabilities in specific sectoral systems (for example consumer electronics or digital imaging). Ownership of these entities by universities, as opposed to nonpracticing entities, augers well for the attainment of increased international commercialisation on account of the prevalence of shared injunctive norms with the academic knowledge producers and individuals working within user-enterprises.

Our paper has also implications for research. Firstly, the propositions developed here could be operationalised into quantitative variables: thus, offering scope for the conduct of research across a broader range of national and organisational contexts (indeed, a key limitation of our research - identified in the third Section - was the narrow, technology-focused and research leading, organisational context examined here). Secondly, the use of institutional theory, and particularly constructs exploring the space between institutional fields, could be particularly useful in deciphering the emergence of new rules, and their implications for institutionalisation processes. We believe that research in this context could also influence institutional theory. Lastly, we believe that there is scope for further research in examining the international commercialisation of university-generated knowledge from the perspective of nonpracticing entities. Apart from providing novel insights into the processes at work, their success in pooling IP could inform the creation of new university-led organisations aimed at commercialising IP.

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The role of spatial and non-spatial forms of proximity in knowledge transfer

A case of technical university

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Abstract

Purpose – The purpose of this paper is to advance the comprehension of the role that geographic proximity plays in relation to non-spatial proximity in the context of international university-industry knowledge transfer.

Design/methodology/approach – The paper is designed as a multiple-case study. It looks at selected instances of contract research at Tallinn University of Technology that represents a typical technical university in Central and Eastern Europe characterised by relatively short period of market economy and university-industry cooperation.

Findings – The results indicate that there emerge different configurations of proximity nationally and internationally. In case of domestic cooperation cognitive (education), organisational, social and institutional (institutional setting) proximity exist simultaneously with geographic proximity. International cooperation is characterised by lack of geographical proximity, but the existence of cognitive and social proximity indicating a substitution.

Research limitations/implications – The research is limited to analysing instances of contract research and relations between spatial and non-spatial forms of proximity. Further research could consider the differences between various channels of knowledge transfer and address the relationship between non-spatial forms of proximity.

Originality/value – The paper contributes to the existing body of knowledge by using proximity dimensions operationalised at aggregate and individual levels to study the university knowledge network. It is proposed in this paper that attention has to be paid to distinguishing between organisational and individual levels of analysis and their differing results. Proximity at organisational level does not necessarily translate into proximity between individuals and vice versa.

Keywords Knowledge transfer, Proximity, University-industry cooperation

Paper type Research paper

1. Introduction

Acquiring new knowledge from external sources has become a common strategy for organisations. The reasons behind this phenomenon include growth in the volume and specialised-technical nature of knowledge, increased technology brokering, the movement in some industries to open standards and a greater variety of actors involved in innovation (Hewitt-Dundas, 2013; Bercovitz and Feldmann, 2006). Universities as the main producers of new knowledge are seen as central actors, which contribute to economic development, innovation and the competitiveness of companies, regions and countries (D'Este and Perkmann, 2011; Huggins *et al.*, 2008, 2012).

Knowledge transfer can be defined at a general level as the push for increased interactions between universities, the economy and society and for knowledge to be more "useful" (Wersun, 2010). van Gils (2010) has stated that no shared classification of knowledge transfer channels exists, and studies have produced contrasting results as

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to their importance. These activities can, nevertheless, be divided into academic engagement/knowledge focused research collaborations (collaborative research, contract research, consulting, informal activities) and commercial engagement/property focused collaborations (patenting and licensing of inventions, spin-offs) (Perkmann *et al.*, 2013; Bozeman *et al.*, 2013). The difference is, for example that contract research is usually characterised by the enterprise defining a more applied problem and financing the work; while collaborative research is more often supported by public funding (D'Este and Perkmann, 2011).

It is acknowledged that next to national cooperation much knowledge transfer takes place internationally, as it allows universities to establish networks and pursue international markets to withstand global competition (Garrett-Jones and Turpin, 2012) and enterprises to be more competitive on international markets and keep up with progress in science and technology (Mason and Wagner, 1999). However, while there is abundant literature on knowledge transfer taking place in a national context (Perkmann *et al.*, 2013; Ankrah and Al-Tabbaa, 2015), the international aspect of knowledge transfer between university and enterprises is less frequently addressed (Mason and Wagner, 1999). The concept of proximity, meaning often only geographical proximity, has been used to understand international university-industry relations (e.g. Simmie, 2003; Arundel and Geuna, 2004). The notion that proximity contains in addition to spatial dimension also non-spatial forms has been recognised in some studies that have used various proximity dimensions, such as geographical, organisational, technical, cognitive, social and institutional proximity (e.g. Petruzzelli, 2008; Slavtchev, 2013; Hansen, 2015). The studies conducted have been mainly quantitative and their results are dependent upon the measures that have been used for the same type of proximity. That is why there is a need to understand better the relations between different measures of proximity dimensions as different operationalisations may lead to different conclusions (Hansen, 2015).

There is, therefore, a research gap related to understanding international knowledge transfer from the university perspective based on the multi-dimensional concept of proximity. This paper seeks to contribute to addressing this gap by using a qualitative multiple-case study design and focusing on the knowledge network at national, European and global level of Tallinn University of Technology (TUT) in Estonia. TUT is an example of a technical university characterised by relatively short period of belonging to the market economy and having close relations with industry. During the Soviet period applied research was only partly conducted there, like in other technical universities in Central and Eastern Europe (Gál and Ptaček, 2011). Thus, the knowledge network that university currently has with enterprises and other external actors is not well-established and mature, but is developing and widening constantly.

The aim of the paper is to advance the comprehension of the role that geographic proximity plays in relation to non-spatial proximity in the context of international university-industry knowledge transfer. More specifically, the study seeks to answer the following research question:

RQ1. How geographic proximity is complemented and/or substituted by cognitive, institutional, organisational and social proximity in case of knowledge transfer between university and enterprises.

The paper contributes to the existing body of knowledge by using proximity dimensions operationalised at aggregate and individual levels to study the international knowledge network that university forms with enterprises in the area

of contract research. It adopts the university perspective and complements the few existing studies that have looked at dimensions of proximity that emerge from cooperation with domestic and foreign partners. It is proposed in this paper that attention has to be paid to distinguishing between organisational and individual levels of analysis and their differing results. Proximity at organisational level does not necessarily translate into proximity between individuals and vice versa.

The paper is structured as follows: the literature review provides an overview of the main theoretical concepts. The next section introduces the research method. In the results and discussion part of the paper the complementarity and substitution between spatial and non-spatial forms of proximity are presented and discussed. This is followed by conclusions.

2. Literature review

2.1 Studies on international knowledge transfer

Several literature reviews on entrepreneurial transformations in university and university-to-industry knowledge transfer have been compiled (Agrawal, 2001; Jacobsson, 2002; Rothaermel *et al.*, 2007; Perkmann and Walsh, 2007; Yusof and Jain, 2010; Bozeman *et al.*, 2013; Perkmann *et al.*, 2013; Ankrah and Al-Tabbaa, 2015) that indicate growth in volume in the field but also its fragmented nature in terms of the topics analysed and the theories employed. The literature on international knowledge transfer in university-industry relations is less abundant than studies on knowledge transfer within the national context. However, studies embodying the university perspective have looked at the strategic framework conditions for successful knowledge transfer, how these activities take place and what influences them (Dooley and Kirk, 2007; Petruzzelli, 2008; Tijssen *et al.*, 2009; Edler *et al.*, 2011; Slavtchev, 2013). Another important area is the conceptual development of the field either by combining different perspectives (e.g. regional innovation systems approach, new production of technology theory, triple helix model and social network theory) or developing a specific one (e.g. transnational academic capitalism) (Fromhold-Eisebith and Werker, 2013; Kauppinen, 2012).

Such theoretical approaches as entrepreneurial university and academic capitalism are present (e.g. Dooley and Kirk, 2007; Kauppinen, 2012), but there is less variety in the theoretical approaches compared to studies of knowledge transfer in the national context. Furthermore, in a few cases, various dimensions of proximity (geographical, organisational, technical, cognitive, social and institutional) are used as the basis for explaining the variations in interactions between geographically distant actors, including also international ones (e.g. Petruzzelli, 2008; Slavtchev, 2013).

The majority of studies on international knowledge transfer adopt the enterprise perspective in that they analyse cooperation between universities and enterprises from the point-of-view of the latter. These types of articles focus on MNEs, analysing, for example, the factors that influence the cooperation of subsidiaries of MNEs with local universities (Broström *et al.*, 2009; Li, 2010; Manolopoulos *et al.*, 2011), internationalisation of R&D and the knowledge transfer activities MNEs engage in developing countries (China, India) (Jull Sørensen and Hu, 2014; Harryson *et al.*, 2008; Krishna *et al.*, 2012) and developed regions (Belderbos *et al.*, 2014). Another stream of studies that uses the enterprise perspective looks at enterprises of different sizes in a specific sector (engineering, biotechnology, manufacturing, cleantech, aviation) or in a specific region or country group to explore on what basis they form innovation

networks and at which spatial level these are located (Freel, 2003; Arundel and Geuna, 2004; Simmie, 2003; Broström, 2010; Malik, 2013; Rõigas *et al.*, 2014; de Zubielqui *et al.*, 2015; Broekel and Boschma, 2012; Hansen, 2015; Steinmo and Rasmussen, 2016).

Such issues as the absorptive capacity of enterprises (depending also on their size) related to cognitive proximity, level of innovativeness (Freel, 2003; Rõigas *et al.*, 2014), geographical proximity (Simmie, 2003; Arundel and Geuna, 2004), research orientation of cooperation (Broström *et al.*, 2009; Li, 2010) emerge from these studies as factors influencing the outcomes of knowledge transfer. The dimensions of proximity have been studied in terms of different types of enterprises and changes over time (Steinmo and Rasmussen, 2016), different proximity dimensions required in case of network formation and node performance (Broekel and Boschma, 2012) and dynamics between the dimensions of proximity (Hansen, 2015).

To summarise, there are only a few studies specifically addressing international knowledge transfer between universities and enterprises from the university's perspective. It has been more commonly studied as part of the R&D internationalisation of MNEs or the regional-national-international innovation networks of enterprises. There are some studies that use the concept of proximity from the university's perspective and include into the analysis also international level.

2.2 Forms of proximity and their inter-relations

There is a vast literature that examines the importance of location and spatial closeness for knowledge networks and innovation (Knoben and Oerlemans, 2006). In addition to geographical proximity that has been shown to contribute to learning and innovation, also non-spatial forms of proximity have been found to influence knowledge transfer (Boschma, 2005). However, the number of dimensions of proximity used in previous studies varies and there is conceptual overlap between them (Knoben and Oerlemans, 2006). In the current paper five dimensions of proximity are used.

Geographical proximity is defined in terms of the spatial or physical distance between actors (Boschma, 2005). The critical role of geographic proximity of knowledge providers and users has been recognised in literature as it facilitates the transfer of tacit knowledge due to closer interactions (Knoben and Oerlemans, 2006). Geographical proximity is needed more in case of more applied cooperation with shorter time to market (Broström, 2010), in certain stages of knowledge transfer (Torre, 2008), and between different types of organisations (Ponds *et al.*, 2007). However, there is also a growing body of evidence in favour of distant knowledge sources (Olechnicka, 2012). Temporary geographic proximity has been proposed as a means to alleviate the problems created by geographic distance through meetings, short visits and temporary co-location (Torre, 2008).

Cognitive proximity means that actors share a similar knowledge base and expertise (Boschma, 2005). What is important here is the ability to learn or absorptive capacity; that is, "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990). The higher absorptive capacity of organisations increases the cognitive proximity between partners, even if they are geographically distant (De Jong and Freel, 2010), but too much cognitive proximity could be harmful in terms of novelty and learning (Nooteboom *et al.*, 2007). Cognitive proximity may increase over time, for example when social proximity and trust-based relations emerge (Boschma, 2005).

Organisational proximity characterises the extent to which actors belong to the same institutional arrangements like networks, alliances, clusters and consortia, and implies some form of inter-dependence and control between them (Boschma, 2005). Organisational proximity can be understood also as similar organisational context of interacting partners that facilitates mutual understanding (Knoben and Oerlemans, 2006), which indicates a certain overlap with institutional proximity and is not used in the current paper. It is rather assumed that the degree of hierarchy between organisations contributes to cooperation by decreasing uncertainty and opportunism (Hansen, 2015).

Social proximity consists of trust-based relations between partners and is likely to be stimulated by geographical proximity (Boschma, 2005). Studies on trajectory (old) and intentional (new) networks have found that previous interactions contribute to the formation of strong trusting relationships for accessing knowledge, while newer connections tend to be weaker and more formalised (Sousa and Fontes, 2014). It has been found that academics tend to have higher number of linkages with locations where they have defended their academic degrees and where their colleagues and students have established start-ups, indicating the importance of shared background and experience (Slavtchev, 2013). Trust and commitment are likely to develop with time as partners become more familiar with each other and the possibility for opportunistic behaviour decreases (Boschma, 2005).

Institutional proximity consists of formal (laws and rules) and informal (cultural norms, habits and values) institutions (Boschma, 2005). Knowledge transfer involves various actors with different norms and values. Studies have looked at university-industry-government relations based on the triple helix principle (Ponds *et al.*, 2007). Siegel *et al.* (2003) distinguish within the university between academics and technology transfer specialists. Researchers are mainly interested in recognition within the scientific community in the form of publications and citations, but also in additional finances. Technology transfer specialists are seeking to protect and market the university's intellectual property and, second, to facilitate technology transfer and secure additional funding. As the third type of actor, the enterprises are mainly interested in the financial gain and, second, in maintaining control over their technologies. The fourth type of actor is the government that sets the regulatory environment and is interested in adopting measures that would lower the cooperation barriers between university and industry (Rõigas *et al.*, 2012) because when the institutional context is too different then even if organisational and social proximity exists between actors, this is not enough (Boschma, 2005). So in addition to norms and values, institutional proximity can be understood as different institutional contexts dependent upon their geographical location (Hoekman *et al.*, 2009).

The previous studies have shown a complex set of relations to exist between the dimensions of proximity characterised by substitution and overlap, and changes over time. Hansen (2015) has found that social, organisational and cognitive proximity can act as substitutes for geographical proximity; whereas between social and geographical, and institutional and geographical proximity there is also overlap. There are differences also between various knowledge transfer activities as compared to developing joint intellectual property, joint research projects require more distant knowledge bases (Petruzzelli, 2008). Related to time, Steinmo and Rasmussen (2016) have shown that for socially and geographically proximate engineering-based firms cognitive proximity is likely to increase over time; while for organisationally and cognitively proximate science-based firms it is social proximity. A difference has also

been found in tie formation and node performance phases as geographical and social proximity contribute to both, while cognitive and organisational proximity are useful only in forming the network (Broekel and Boschma, 2012).

The discussion above indicates that the dimensions of proximity can be explored in the context of international university-industry relations at different levels, including aggregate (meaning national and organisational)[1] and individual, and by various, partially overlapping, measures. It is also evident that the previous studies have been predominantly quantitative. The interview approach has been used for data collection by Broekel and Boschma (2012), Hansen (2015) and Steimno and Rasmussen (2016); whereas the last two studies analyse data also qualitatively.

Based on previous studies, it can be concluded that geographical proximity has been explored at organisational level in absolute and relative terms (Table I). Cognitive proximity has been studied at organisational and individual level. At organisational level it means mainly technological similarity between actors, while at individual level it looks at the similarity of educational backgrounds of individuals. Organisational proximity has been analysed at organisational level denoting either hierarchical dependencies between organisations or similarities in organisational type (mainly in the studies that do not use a separate dimension for institutional proximity). Social proximity has been explored at organisational level in terms of actors having partners in common. However, it has been more often studied at individual level meaning previous contacts between individuals. And finally, institutional proximity has been analysed at organisational level as similarities in institutional context (at times the same as co-location) or similarities in organisational type. At individual level it has been seen as common values and norms.

3. Research method

3.1 Study context, design and description of cases

The study is conducted in TUT (founded in 1918). It represents a typical context of technical universities in Central and Eastern Europe that are characterised by relatively short period of belonging to the market economy and having close relations with industry. During the Soviet period, universities had mainly an educational role, while fundamental research was conducted in the institutes of the Academy of Sciences and applied research in state companies and branch R&D institutes (and to some extent in technical universities), and it was EU accession that hastened the creation of knowledge infrastructures at universities through incubators, science parks and technology transfer units (Gál and Ptaček, 2011). It follows, therefore, that the knowledge network that university has with enterprises and other external actors is not well-established and mature, but is developing and widening constantly.

The university is located in the capital of Estonia, Tallinn, and is one of the six public universities and the only technical university (Table II). It has eight faculties: Faculty of Civil Engineering, Faculty of Power Engineering, Faculty of Information Technology, Faculty of Chemical and Materials Technology, Tallinn School of Economics and Business Administration, Faculty of Science, Faculty of Mechanical Engineering and Faculty of Social Sciences.

The study uses a multiple-case study design that enables to conduct a compelling and robust analysis of a contemporary phenomenon in its real-life context (Yin, 2009). Out of 28 instances of contract research that were identified, nine were selected for the study. The aim was to cover maximally different instances of contract

Table I.
Analytical framework: forms of proximity and levels

	Geographical proximity	Cognitive proximity	Organisational proximity	Social proximity	Institutional proximity
Organ sat onal level	Same region, country, outside of country (Steinmo and Rasmussen, 2016) Same region, country, neighbouring countries, other European countries, outside of Europe (Hansen, 2015) Geographical distance in kilometres (Broekel and Boschma, 2012) regional, national and international actors (Petruzzelli, 2008) Same country, same NUTS-1, same NUTS-2 (Balland, 2012) Geographical distance between NUTS-3 regions (Hoekman *et al.*, 2009)	R&D experience and technological similarities (Steinmo and Rasmussen, 2016) Firm specialisation in knowledge segments (Balland, 2012) Technological similarity in terms of technology class and economic activities (Broekel and Boschma, 2012) Technological proximity in terms of patent technological class (Petruzzelli, 2008) Similar technological know-how (Slavtchev, 2013)	Similarities in organisational purposes, functions and experiences (Steinmo and Rasmussen, 2016) Part of same legal entity (Hansen, 2015) Similarities in organisational type (Broekel and Boschma, 2012) Strategic alliances, hierarchical dependencies, technological consortia (Petruzzelli, 2008) Same corporate group (Balland, 2012)	Organisations have partners in common (Balland, 2012)	Similarities in institutional context because of co-location (Hoekman *et al.*, 2009) Similarities in organisational type (Ponds *et al.*, 2007; Balland, 2012) Similarities in organisations' culture in terms of norms and habits (Hansen, 2015)
Individual level		Similarities in educational background (Hansen, 2015)		Previous contacts, cooperation, being former colleagues (Steinmo and Rasmussen, 2016) Previous contacts, mutual acquaintances (Hansen, 2015) Social relations in terms of previous job (Broekel and Boschma, 2012) Common background and experience through repeated interactions (Slavtchev, 2013)	Common values and norms (Slavtchev, 2013)

Source: authors' compilation

research by including into the study as wide a sectoral/disciplinary divide as possible, various enterprise partners and also instances of success and failure. This allowed obtaining information about the significance of various circumstances for the process and outcome of knowledge transfer (Flyvbjerg, 2006). The cases include cooperation between university and domestic/foreign enterprises of various sizes in the areas of technological, physical and social sciences (Table III). The enterprises differ in their R&D orientation from R&D being key part of firm's operations to having small R&D projects. The cooperation consists of basic and applied research, testing and developmental work that has ended after the first phase in several months or has continued in several steps and diversified into other areas over a number of years.

3.2 Methods of data collection

The data concerning contract research was gathered using document analysis and semi-structured in-depth interviews. The country's and university's regulations, university's annual R&D reports, financial documents, web pages, news and press releases were examined to obtain background information characterising the knowledge transfer activities. Electronic registries like Estonian Research Portal (ETIS) and European Patent office patent search (Espacenet) were used to obtain comparable information about the instances of contract research and organisations that cooperated.

The interviews were conducted to obtain, first, the accounts of experiences of the participants; and, second, insights into the wider context of knowledge transfer. The criteria for selecting academics, business support professionals and entrepreneurs were their previous experience with knowledge transfer between the university and enterprises that they were asked to describe retrospectively. The interviews with university managers and senior civil servants responsible for research and innovation policy development and implementation provided additional context for the study at both organisational and country level.

The interview schedules consisted of four main sections of questions: knowledge production, knowledge transfer (including international activities), actors and relationships, governance and management of knowledge transfer. The interview schedule was similar for the target groups with slight variations depending on the interviewee's profile.

The sampling technique consisted of non-random purposeful sampling including criterion sampling and snowball sampling (Patton, 2002). In total 20 interviews with five stakeholder groups were carried out: senior university managers ($n = 2$), technology transfer specialists ($n = 2$), academics ($n = 8$), enterprises ($n = 4$) and policy makers ($n = 4$). First, criteria were set for the interviewees to belong to each of these target groups covering different specialties and outcomes of knowledge transfer and,

Table II. Key figures concerning the university's knowledge production in 2013

No. of teaching and research staff	No. of students	No. of PhD awarded	No. of patents granted	No. of publications	No. of citations	Average citation per paper	*h*-index
1,155	13,050	54	1	308	867	2.8	11

Sources: Scopus data; TUT Annual Research and Development Report 2013 (2014)

Table III.
Overview of cases of contract research between university and enterprises

Case no.	Location and size of enterprise[a]	Speciality[b]	Type of activity[b]	Duration of contract research	R&D orientation of enterprise (Autio, 1997; Steinmo and Rasmussen, 2016)	Outcome for university
1	Large Estonian subsidiary of large Swedish enterprise	Production technology, physical planning, economics	Applied research	1.4 years	Own R&D team. Long experience with R&D	Same type of cooperation has continued in several phases, and in parallel projects, and broadened also into other areas (collaborative research, training, internships, student theses, equipment, sponsorship)
2	Large Japanese enterprise	Informatics, production technology	Applied research	1.4 years	Own R&D unit. Long experience with R&D	Same type of cooperation has continued in several phases and in parallel projects
3	Large Estonian subsidiary of large Dutch enterprise	Thermal engineering, material engineering, transport technology	Applied research, testing and developmental work	1 year	Several smaller projects conducted by different partners	Cooperation is on-going, and has broadened also into other areas (sponsorship, equipment)
4	Micro Estonian enterprise	Technology of other products	Basic research, testing and developmental work	10 months	Low R&D experience, but intention to increase R&D activity	Cooperation is on-going
5	Small Estonian enterprise	Computer engineering	Basic and applied research	No information	R&D is a key part of the firm's operations. The firm spun off from university	Cooperation is on-going in several areas (collaborative research, student theses, internship, equipment)
6	Large Italian enterprise	Electrical engineering	Basic research	3 months	R&D is a key part of the firm's operations Long experience with internal R&D	Cooperation has ended

(*continued*)

Case no.	Location and size of enterprise[a]	Speciality[b]	Type of activity[b]	Duration of contract research	R&D orientation of enterprise (Autio, 1997; Steinmo and Rasmussen, 2016)	Outcome for university
7	Medium-sized Estonian enterprise	Mechanical engineering, hydraulics, vacuum technology, vibration acoustic engineering	Basic and applied research, testing and developmental work	5 months	Several smaller projects conducted by different partners	Cooperation is on-going in several areas (collaborative research, contract research, internships, student theses)
8	Large German enterprise	Water transport technology	Applied research	5 months	Own R&D team. Long experience with R&D	Cooperation has ended
9	Large US enterprise	Medical technology	Basic and applied research	2 years	R&D is a key part of the firm's operations. Long experience with internal R&D	Cooperation has ended

Notes: [a]Enterprise sizes are based on the following Eurostat categories: large = 250 or more employees, medium = 50-249, small = 10-49, and micro = 1-9. [b]Speciality and type of activity are based on categories used in Estonian Research Portal
Source: Authors' compilation

Table III.

second, after the initial interviews had been conducted, the interviewees suggested other persons with whom they had cooperated to be interviewed. The interviews were carried out in April-June 2014 and lasted 1-1.5 hours on average. Interviews were recorded and transcribed.

3.3 Methods of data analysis

The data rendered by document analysis and interviews was analysed using an analytical framework derived from previous research that employed the concepts of geographical, cognitive, organisational, social and institutional proximity. The dimensions of proximity were operationalised at aggregate (organisational) and individual levels.

Geographical proximity was measured at organisational level as spatial distance between university and enterprise in kilometres (Steinmo and Rasmussen, 2016) by looking at distance between the cities where partners were located. Cognitive proximity was analysed at two levels: organisational and individual. At the organisational level it meant university and enterprise having comparable R&D experience and technological similarities (Steinmo and Rasmussen, 2016). At individual level it was studied whether individuals involved in cooperation had similar educational background (Hansen, 2015). Organisational proximity was understood at organisational level as university and enterprise belonging to the same legal entity (Hansen, 2015) in terms of formal networks, alliances, clusters and technological consortia.

Social proximity was operationalised at organisational level as organisations having previously partners in common (Balland, 2012) and at individual level in terms of individuals involved in cooperation having former contacts, mutual acquaintances (Hansen, 2015). And finally, institutional proximity was measured at organisational level by university and enterprise belonging to similar institutional setting in terms of co-location (Hoekman *et al.*, 2009) influencing legislation, national culture; and at individual level as common values and norms (Slavtchev, 2013).

The relations between spatial and non-spatial forms of proximity were studied by using the concepts of complementarity and substitution (Hansen, 2015). Thus, complementarity between spatial and non-spatial forms of proximity exists when geographical and other forms of proximity are simultaneously present, while substitution refers to the absence of geographical proximity that is being compensated by various forms of non-spatial proximity (Hansen, 2015).

The interview data was subjected to qualitative content analysis by using open coding and assigning initial descriptive codes to text (Saldaña, 2009). It was then organised into a partially ordered descriptive matrix based on the mentioned analytical categories that allowed making comparisons between cases; and analysis proceeded with variable-by variable matrix to explain relationships (Miles *et al.*, 2014).

3.4 Limitations

The limitations of the study are related to covering cases in which instance there was at least short-term cooperation. This leaves aside cases where the cooperation failed to start that might be differently influenced by spatial and non-spatial forms of proximity. In terms of the interviews, another limitation is that because no foreign enterprises were interviewed, the data is university and country-centred, and the results should be viewed as looking at the inside-out direction rather than outside-in.

4. Results and discussion

4.1 Overview of spatial proximity

The cases of contract research between university and enterprises analysed in the current study are characterised by different configurations of proximity dimensions. Overview of the various forms of proximity that apply to the nine cases at the start of the cooperation is provided in Table IV. Geographical proximity allows to distinguish between cooperation with domestic and foreign enterprises as those that are located in Estonia (in capital city Tallinn or its vicinity) are nearer in terms of spatial distance in kilometres than those located abroad (Germany, Italy, Japan and USA).

The results indicate that domestic cooperation takes place between university and enterprises of different sizes, while foreign enterprises are larger. It reflects the university's aim to build its knowledge network with enterprises and balance working with domestic and foreign long-term strategic partners and local SMEs, as university manager explains: "We have a list of partners that are long-term, who have finances and can offer something interesting for researchers. We try to compensate with this the need to provide services to [local] SMEs" (UM1)[2]. Higher physical proximity in collaborations between university and SMEs than in case of university and large firms is in line with other findings (Slavtchev, 2013). The reason is that smaller firms use mainly indirect (published research results) rather than direct university-industry links and tend to rely on other organisations than universities (de Zubielqui *et al.*, 2015). Under the conditions of limited resources, they also have to find the best fit between intellectual contribution and the costs of cooperation over long distances (Slavtchev, 2013).

4.2 Complementarity between spatial and non-spatial forms of proximity

The results of the study show that geographical proximity is complemented by non-spatial forms of proximity on a number of occasions. In case of domestic cooperation, it can be observed that cognitive proximity, operationalised at individual level as education, organisational proximity, social proximity, analysed at organisational level as organisational contacts and at individual level as personal contacts, and institutional proximity, understood at organisational level as institutional setting, tend to co-exist with geographical proximity (Table V).

The instances of domestic contract research are characterised by cognitive proximity not so much in terms of similarities in R&D and technology of organisations, but in terms of educational background of individuals. It means, first, that although most of the domestic enterprises do not share cognitive proximity, operationalised at organisational level as R&D and technology, with the university, it can develop over time supported by the growth of trust. It allows cooperation to develop step-by step as academic related to Case 1 states: "The initial objective was to show what university is capable of. Enterprise was satisfied and now we are negotiating about a new contract" (A5). Second, firms of different sizes, R&D experience, absorptive capacity can contact the university. Since the university TT office has a fixed pool of academics to whom to turn to carry out the projects, more localised networks emerge. TT officer describes the situation so that: "My first aim is to find if there is a person at the university who has something to offer to the firm. […] It often happens that one person does not answer and there just are no others for whom the topic would be suitable" (TTO2). Third, another aspect is that in a small country with one technical university the probability of finding university graduates working in industry in their field is relatively high as stated by an academic in

Table IV.
Characteristics of proximity dimensions of the cases of contract research between university and enterprises (at the start of cooperation)

Case no.	Cognitive proximity	Organisational proximity	Social proximity	Institutional proximity
High geographical proximity				
1	Corporate group and university have numerous patents in similar areas, Estonian subsidiary does not have patents, but is oriented towards product development. Some individuals had similar production technology background	Organisations belong to the same professional networks (association, cluster), and have established their own cooperation body	Organisations had partners in common Individuals had mutual acquaintances due to cooperation in other areas (collaborative research, education and training, sponsorship)	Institutional differences regarding legislation (procedures not in place) as cooperation involved local subsidiary and main office located abroad Differences in negotiations style and expectations regarding timing (long preparation phase, delays), difficulties accessing data, making results public
3	Corporate group and university have patents in similar areas, Estonian subsidiary does not have patents, university is more experienced in R&D. Individuals had similar thermal engineering background	Organisations belong to the same cluster	Organisations had partners in common Individuals had previous contacts via professional network that had been established earlier	Institutional similarities because of co-location, although foreign-owned, local CEO is Estonian. Differences in expectations regarding making the results public, difficulties accessing data
4	Firm does not have patents, university is more experienced in R&D. Individuals had different backgrounds in economics, law, engineering	Organisations are not organisationally related	Organisations did not have partners in common Individuals had no previous contacts	Institutional similarities because of co-location Differences in expectations regarding organisation of work (deadlines, feed-back), priorities (teaching/research vs servicing firms)
5	Firm has spun-off from university and has trademarks, both organisations are experienced in R&D. Individuals had similar computer engineering background	Organisations belong to the same technological consortia, firm is academic spin-off	Organisations had partners in common. Individuals had previous direct contacts via professional networks and cooperation in other areas (education and training, collaborative research, equipment)	Institutional similarities because of co-location Similarities in academic norms as firm is university spin-off and R&D is part of its main activities, firm is "life-style" business

(*continued*)

Table IV.

Case no.	Cognitive proximity			stitutional proximity
7	Firm does not have patents, university is more experienced in R&D. Individuals had similar machine mechanics background	organisationally related	common Individuals had mutual acquaintances due to previous cooperation in other areas (education and training, collaborative research)	stitutional similarities because of co-location Differences in level of specialisation (cooperation possible at general level only)
Low geographical proximity				
2	Organisations have patents in similar areas and are experienced in R&D. Some individuals had similar information technology background	Organisations are not organisationally related	Organisations had partners in common Firm had first cooperation with state level which suggested the enterprise could commission research from university and individuals had mutual acquaintances	Institutional differences in terms of culture (communication style and dressing norms, emphasis on hierarchy), regulations (format of presentation of results, payment rules) Similarities in organisation of work and work culture, academic norms as in the corporate group there is separate research-oriented think-tank and entrepreneurial spirit was said to be high among academics
6	Organisations have patents in similar areas and are experienced in R&D, firm is more development than research oriented. Individuals had similar engineering background	Organisations are not organisationally related	Organisations did not have partners in common Individuals had no previous contacts, firm's representative heard academic's presentation at conference concerning the technology in question	Institutional differences regarding regulations and national culture due to being located in different countries Lack of focus and not agreeing on goals, although firm engineers were familiar with the topic, they wanted too complex things. Uncertainty because the ownership of the firm had recently changed

(*continued*)

Table IV.

Case no.	Cognitive proximity	Organisational proximity	Social proximity	Institutional proximity
8	Firm does not have patents, but has own engineering team, both organisations are experienced in R&D. No information about educational backgrounds	Organisations are not organisationally related	Organisations had partners in common Firm had first cooperation with state level, during which some individuals involved in contract research came into contact	Institutional differences regarding regulations due to being located in different countries Some similarities in negotiations style, relatively easy and quick preparation phase
9	Organisations have patents in similar areas and are experienced in R&D, firm is both research and development oriented. Individuals have similar engineering background	Organisations are not organisationally related	Organisations had partners in common Academic had previous cooperation with the firm through his academic spin-off	Next to institutional differences regarding regulations, there was open attitude towards people from other culture, not emphasising positions in work and society Firm R&D staff had higher level of practical skills, greater speed of decision-making and working

Source: Authors' compilation

Table V. Complementarity and substitution between spatial and non-spatial forms of proximity

Relations between spatial and non-spatial proximity	Geographical proximity	Cognitive proximity		Organisational proximity	Social proximity		Institutional proximity	
	Spatial closeness	R&D and technology	Education	Common formal networks	Organisational contacts	Personal contacts	Institutional setting	Individual norms
Complementarity	Case 1 Case 3 Case 4 Case 5 Case 7	Case 5	Case 1 Case 3 Case 5 Case 7	Case 1 Case 3 Case 5	Case 1 Case 3 Case 5 Case 7	Case 1 Case 3 Case 5 Case 7	Case 3 Case 4 Case 5 Case 7	Case 5
Substitution		Case 2 Case 6 Case 8 Case 9	Case 2 Case 6 Case 9		Case 2 Case 8 Case 9	Case 2 Case 8 Case 9		Case 2

Source: Authors' compilation

Case 3: "It turned out that a graduate of thermal engineering is responsible for technical design in the enterprise" (A6). In a larger context with multiple actors, namely in Danish cleantech industry, Hansen (2015) has found the contrary; namely, that the sector is not dependent upon local specialized networks as cooperation partners do not share a common educational background.

Geographical proximity is additionally complemented by organisational proximity. This indicates that spatially closely located organisations tend to be involved in the same professional networks like associations, clusters, technological consortia. It is especially true for larger firms with more resources, but also for more R&D intensive firms like subsidiaries of foreign corporations and academic spin-offs. However, in Danish cleantech industry no such overlap has been found as being within the same group is not likely to contribute to intra-regional cooperation (Hansen, 2015). Since the present study looks only at cooperation between different types of organisations, universities and enterprises, it might be argued that organisational proximity is here more important for establishing cooperation than in case of firm-to-firm cooperation.

Also social proximity accompanies geographical proximity as being located in the same city or its vicinity and/or belonging to the same networks enables organisational and personal contacts. Social proximity at organisational level is a combination of belonging to common formal networks (organisational proximity) and previous contacts between individuals (social proximity at individual level) that create familiarity and trust. Domestic partnerships have been found to be characterised by increased social proximity also in other studies (Hansen, 2015). This does not mean that cooperation cannot be initiated without social proximity, it is possible for it to develop over time as an enterprise representative in Case 4 explains: "At first we thought that the idea has some value and whether it's worth to share it with someone else. But this view has changed a lot over time […] just this kind of trust has to emerge" (E1).

Institutional proximity in the form of individual values and norms is mostly not complementary with geographical proximity. Exception here was Case 5, where the academic spin-off shared individual level norms with university academics due to being located in the same building, having close cooperation in various forms and emphasising the importance of academic/entrepreneurial "life-style". However, institutional proximity in the form of institutional setting is complementary with geographical proximity as partners share regulations and national culture. Exception here was Case 1, where the subsidiary was influenced by the country where it was located as well as by the corporate culture of its foreign main office. In addition, academics and students involved in the cooperation came from different countries and represented various national cultures. In other instances, cooperation involved mainly persons of the same nationality and there was no need to use foreign language (except for Case 3) or adjust to different regulations. It has been found also previously that there is a strong correlation between geographical and institutional proximity when the latter is measured through belonging to the same country (Hoekman *et al.*, 2009).

4.3 Substitution of spatial proximity by non-spatial forms of proximity

The results of the study indicate also instances where substitution occurs. The absence of geographical proximity in case of international cooperation can be substituted by cognitive proximity, at both organisational and individual levels operationalised as R&D and technology, and education, and by social proximity, also at both levels understood as previous organisational and personal contacts. The cases of

international contract research are characterised by R&D and technological similarities as the foreign enterprises have long-term experience in R&D and have patents in the same area as the university. It has been found in other studies that the likelihood of R&D intensive firms to engage into collaboration with university, when they share similar technological know-how, is relatively high and can made the distant collaborations worthwhile (Slavtchev, 2013). However, this is not the case with all channels of knowledge transfer as collaborative and explorative relationships (collaborative research) require more distant knowledge bases to enable novelty and creativity (Petruzzelli, 2008).

There is also substitution of geographical proximity by cognitive proximity, captured at individual level as education, since the educational background of individuals involved in international cooperation is mostly similar (except for Case 8). This is because, like in case of domestic cooperation, the university TT office is usually the one that mediates the enterprise contact and finds appropriate cooperation partners inside the university. Also larger and/or more R&D intensive firms have their own R&D personnel that are likely to have similar educational background as the university researchers like it was elaborated by an academic in Case 9: "I met with people from the research lab [of the enterprise], many of whom had PhD degrees. They were applied researchers and developmental engineers, but also researchers and developers with medical background" (A8). This finding is line with Hansen (2015) who has concluded that international collaborations are more likely to have cognitive proximity in terms of similar educational background.

Social proximity, at both organisational and individual levels, was also found to compensate for the absence of geographical proximity in international cooperation. In two cases (Case 2, Case 8) foreign firms had previous cooperation with Estonian governmental bodies indicating the existence of previous mutual acquaintances and in one case there was direct previous cooperation with the academic (Case 9). Cooperation that occurs without social proximity tends to be shorter like in Case 6, in which instance the development of social proximity over time was complicated due to the unclear aims of the enterprise caused by a recent take-over. Looking at personal relations between individuals, Hansen (2015) has also found that partnerships outside of Europe are characterised by social proximity; while Balland (2012) 1has stated at organisational level that organisations are not more likely to start collaboration with partners of partners. So organisational-level prior contacts have to be complemented with individual-level contacts in order to allow for trust to emerge, and this is more likely to happen in bilateral collaborations than in case of cooperation involving multiple partners (Balland, 2012).

There is some additional evidence of a substitution of geographical proximity by institutional proximity apparent only in Case 2. Institutional proximity, operationalised at individual level as values and norms, can be said to be partly similar as according to the academic who was involved in that case: "The other party has commented that they have enjoyed working with Estonia because entrepreneurial spirit was high among the academics" (A2). There is also some evidence of a substitution of geographical proximity by institutional proximity, understood as institutional setting, but this has occurred over time. Hansen (2015) noted that social proximity acts as an intermediate in this kind of substitution between geographical and institutional proximity. In the current study in Case 2 the academic noted about coping in different culture that: "Polite person reads and does homework. […] But written guidelines can differ from reality. […] It happens through learning. It takes time […] it was made easier by the

fact that enterprise representative visited Estonia every month" (A2). It follows that compensating the absence of geographical proximity with institutional proximity can be said to happen over time through learning and increased social proximity (trust) enabled by temporary geographical proximity.

To conclude, some forms of non-spatial proximity both complement and substitute geographical proximity, while others only complement or substitute. First, cognitive proximity captured at individual level as education and social proximity, at organisational and individual level, complement as well as substitute geographical proximity. This means that cognitive proximity, understood as educational similarities, and social proximity tend to exist in case of domestic cooperation (overlap), and also during international cooperation (substitution). Second, in case of organisational proximity and institutional proximity, operationalised at organisational level as institutional setting, there is only overlap with geographical proximity as in terms of spatially close cooperation also these other forms of non-spatial proximity tend to be present. Finally, between cognitive proximity, understood at organisational level as R&D and technology, and geographical proximity there is only substitution as the absence of geographical proximity in case of international cooperation can be substituted by R&D and technological similarities that exist between partners.

The complementarity and substitution between spatial and non-spatial forms of proximity depends partly on the level of analysis (aggregate or individual), but also on the type of cooperation, type of knowledge, duration, number and type of partners. In terms of level of analysis, geographical proximity and cognitive proximity, understood at individual level as education, are complementary in case of domestic cooperation; while geographical proximity and cognitive proximity, measured at organisational level as R&D and technological similarities, are not. Similarly, geographical proximity and institutional proximity, operationalised at organisational level as institutional setting, are overlapping; while geographical proximity and institutional proximity, understood at individual level as individual norms, are mostly not.

5. Conclusions

The study explored selected instances of contract research carried out at TUT. The study context represents a typical technical university in Central and Eastern Europe that is characterised by relatively short period of belonging to the market economy and having close relations with industry. The study aimed to advance the comprehension of the role that geographic proximity plays in relation to non-spatial proximity in the context of international university-industry knowledge transfer. For that purpose the following research question was addressed: how geographic proximity is complemented and/or substituted by cognitive, institutional, organisational and social proximity in case of knowledge transfer between university and enterprises.

The current study developed an analytical framework consisting of five spatial and non-spatial proximity dimensions (geographical, cognitive, organisational, social and institutional proximity), operationalised at organisational and individual levels. The relations between spatial and non-spatial forms of proximity were further analysed by using the complementarity/substitution approach. Complementarity meant that geographical and other forms of proximity exist simultaneously, while substitution indicated that the absence of geographical proximity was compensated by various forms of non-spatial proximity (Hansen, 2015).

It can be concluded from the findings that although university is still building its knowledge network with external actors due to the relatively short period of market

economy and closer relations with industry, international and domestic cooperation are characterised by different dynamics regarding proximity dimensions. In case of domestic cooperation, geographic proximity and cognitive (education), organisational, social and institutional (institutional setting) proximities exist mostly simultaneously. Geographic proximity that enables those non-spatial forms of proximity helps enterprises with limited R&D intensity and university-industry cooperation experience, that is lack of cognitive proximity in terms of R&D and technological similarities, to access university generated knowledge. Boschma (2005) states that cognitive proximity is dynamic, and organisational and social proximity can be used to increase it. This was the case with some of the SMEs that had contacted the university because it was close, and this allowed finding more immediate solutions to existing problems. Also in other studies (e.g. Broström, 2010) geographic proximity is seen as a critical factor for R&D projects with a short time to market as opposed to long-term research projects.

International cooperation is characterised by the absence of geographical proximity, but by the existence of cognitive and social proximity indicating a substitution between those spatial and non-spatial forms of proximity. The similarities in R&D intensity and educational background can be translated into cognitive proximity that helps overcome the challenges of geography in the case of international cooperation. Arundel and Geuna (2004) have found that the importance of geographic proximity declines with an increase in the firm's R&D expenditure and the importance of codified basic research results. This indicates that the firms have to possess internal capabilities/absorptive capacity for deciphering new information and employing to commercial ends.

The paper contributes to the existing body of knowledge by using proximity dimensions operationalised at aggregate and individual levels to study the international knowledge network that university forms with enterprises in the area of contract research. It is proposed in this paper that attention has to be paid to distinguishing between organisational and individual levels of analysis and their differing results. Thus, in terms of domestic cooperation, complementarity at organisational level does not necessarily translate into overlap at individual level in case of geographical and institutional proximity. Similarly, complementarity at individual level is not apparent at organisational level in case of geographical and cognitive proximity. However, this difference between the levels of analysis does not emerge in relation to substitution as in case of international cooperation substitution for geographical proximity is apparent in terms of cognitive and social proximity operationalised at both organisational and individual levels.

Implications for further research include analysing the differences between different channels of knowledge transfer characterised by different number and degrees of involvement of actors and the different nature of knowledge exchanged. In case of contract research, enterprise is mainly the one that defines the problem that is more applied in its nature, and is not so much involved in the cooperation process. Collaborative research, on the other hand, involves greater degrees of communication and mutual effort related to more fundamental research over a longer period of time between multiple actors. Another area for further research is looking in greater detail at the interplay between non-spatial proximity dimensions and between several proximity dimensions simultaneously. It is not only geographical proximity that can be complemented or substituted by other forms of proximity, but social proximity can also have an effect by acting as an intermediate. Additionally, the central role of cognitive proximity in knowledge transfer deserves further attention.

Notes

1. Throughout the paper organisational level is used to denote national and organisational level.
2. Interview extracts are marked with the number of the interview and a letter indicating the interview type as follows: A, academics; TTO, technology transfer officers at university; UM, university managers; E, enterprises; P, political level.

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Brokers in Biotechnology and Software Networks in EU Research Projects

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Abstract: Researchers have acknowledged that the flow of knowledge is influenced by the non-structural and structural features of networks. This paper aims to further develop an understanding of the institutional and structural features of knowledge networks by relating the brokerage roles of actors to the types and locations of organisations in biotechnology and software networks. The study is set within the context of the European Union (EU) research and innovation policy. It is designed as a social network analysis of EU research projects in biotechnology and software that took place between 1995 and 2016, wherein organisations from the Baltic States participated. The results of the study revealed that higher education and research organisations and public bodies acted as the main knowledge brokers and brokered more frequently across

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different regions in biotechnology networks. In software, it was the universities and research organisations that fulfilled this role. Thus, this study contributes to an understanding about the institutional and structural aspects of knowledge networks by focusing on brokers and their brokerage roles and relating these factors to specific organisation types and the locations of actors within the two sectors. It also adds the empirical context of the Baltic States in the areas of biotechnology and software collaborative research projects to the studies of knowledge networks, and offers practical suggestions for implementing collaborative research projects.

Keywords: *brokers, differentiated knowledge base, knowledge networks, social network analysis, brokers, the Baltic States*

1. Introduction

Researchers have acknowledged that the flow of knowledge is influenced by the non-structural and structural features of networks and partnerships across institutional (i.e., countries, industries and technologies) and structural boundaries (Balachandran & Hernandez, 2018). Collaborative research projects consist of the interactions between actors from different sectors, locations and types (i.e., higher education and research, enterprises, public bodies, non-governmental organisations (NGOs), etc.), whose main activities belong to different organisational fields. Thus, organisations follow different types of organisational logics also in their attempts to cooperate with one another (Kalantaridis *et al.*, 2017).

The present study draws on the understanding that differences in sectoral knowledge networks influence the process of innovation. The geographical compositions of sectoral networks have been found to differ. In industries with an analytical knowledge base, like biotechnology, knowledge is often codified, enabling it to be exchanged over long distances (Mattes, 2012). In sectors with synthetic knowledge base, like software, knowledge is more difficult to exchange across geographical distances when there is a dominance of tacit knowledge that requires more specific expertise, craft and practical skill (Asheim *et al.*, 2007). The types of actors who hold a strategic position also varies within networks. In biotechnology, university-industry connections are frequent and important during research, which often results in radical innovation (Asheim *et al.*, 2007). In software, learning occurs

interactively with clients and suppliers, leading to incremental innovation (Asheim *et al.*, 2007). While the network structures of biotechnology firms tend to be larger, centralised, clustered, less dense and more connected, the network structures of software firms are often fragmented and corporate-based (Salavisa *et al.*, 2012).

Like the structural features of networks, organisations' characteristics and geographical locations are important for the flow of knowledge. Nonetheless, these factors have received limited attention (Owen-Smith & Powell, 2004). In terms of structural features, such as brokerage, although a significant amount of attention has been paid to the gatekeepers who influence the flow of knowledge by granting network access to outsiders, networks consist of actors with various brokerage roles. These same actors can simultaneously embody different roles that require closer examination (Chen *et al.*, 2015).

Thus, this paper aims to further develop an understanding of the institutional and structural features of knowledge networks by relating the brokerage roles of actors to the organisational types and locations of biotechnology and software networks. For these reasons, the following research questions were developed: (1) what characterises the knowledge brokers of biotechnology and software networks in terms of organisational type and location; and (2) to what extent do the brokers who represent different organisational types fulfil different brokerage roles (i.e., coordinators, gatekeepers, consultants or liaisons)?

This study is established within the context of the European Union (EU) research and innovation policy that aims to achieve open innovation and science (European Commission, 2016). The objectives of the EU's research and innovation policy are materialised in EU programmes for research and innovation that aim at supporting bottom-up research initiatives. These have evolved from the first framework programme (FP) that was launched in 1983 to FP8, which was initiated in 2013 and later renamed Horizon 2020 (Reillon, 2017). The Baltic States—Estonia, Latvia and Lithuania—have participated in these research and innovation programmes since the 1990s. In addition, they gradually became full members within these programmes when they started the process of EU accession and joined the Union in 2004 (Moedas & Smits, 2015).

This study focuses on the networks of organisations from the Baltic States that participated in EU collaborative research projects (primarily FPs) in biotechnology and software from 1995 to 2016. It uses social network analysis

to study network structure and the Kruskal-Wallis H test to compare groups. The study shows that in both sectors (biotechnology and software), higher education and research organisations, and in biotechnology also public bodies, act more frequently as brokers and broker more often also between different regions. At a practical level, the study adds the empirical context of the Baltic States, in the areas of biotechnology and software collaborative research projects, to the studies of knowledge networks. It also offers practical suggestions for implementing collaborative research projects. The study contributes to the theoretical understanding of the institutional and structural features of knowledge networks by focusing on the sectoral differences between brokers and brokerage roles.

The rest of the article is structured as follows. The theoretical framework section introduces the primary theoretical approaches that explain the institutional and structural boundaries of networks, providing an analytical framework for the study. The methodology section offers an overview of the research approach, sample and data collection and analysis methods. The study's results section presents separate findings for biotechnology and software networks and then discusses the results in the context of previous studies. The final section concludes, highlights the present research's contributions and offers suggestions for further study.

2. Theoretical framework

2.1 Institutional factors

Although the existence of partnerships in multiple domains can enable access to new and distinct sources of knowledge, transferring that knowledge across institutional boundaries can prove costly (Balachandran & Hernandez, 2018). There are a number of institutional differences between the actors. First, collaborative research projects involve interaction between actors of different types (higher education and research, enterprises, public bodies, NGOs, etc.) whose primary activities belong to different organisational fields. Organisational fields are recognised areas of the institutional life of actors that operate within the same domain that can also include organisations that critically influence them (Powell & DiMaggio, [1983] 1991). When considered under the lens of the network theory, organisational fields can consist of the industrial and educational sectors, together with partners, competitors, funding agencies and regulators (Scott, 2008).

It is possible for organisations to imitate environmental elements in their structures and deal with their environments at their boundaries (Meyer & Rowan, 1977). Boundary work involves work within and across various fields. While the former includes maintaining or changing a given field by manipulating its boundaries from the inside, the latter involves protecting or controlling a specific field settlement by relating it to other fields (Helfen, 2015). Configurational boundary work brings together certain actor's activities, leaves others apart and facilitates interaction across physical, social, temporal or symbolic spaces (Langley *et al.*, 2019). This results in the formation of cross-field intersections around shared and changing issues that encompass distinct sets of actors and multiple conflicting logics (Zietsma *et al.*, 2017). Thus, organisations of different types have to overcome different organisational logics and motivations in order to cooperate (Kalantaridis *et al.*, 2017).

Second, EU research projects consist of actors from different geographical locations and of different geographical reach. In addition to the physical distance between the actors, geographical proximity denotes also similarities in institutional context because of co-location (Boschma, 2005; Hoekman *et al.*, 2009). While geographical proximity is helpful in terms of local knowledge spillovers (Grillitsch & Nilsson, 2015), it is neither a sufficient nor necessary condition for learning or interactive innovation (Boschma, 2005; 2018). Nevertheless, geographical proximity has been found to contribute to the development of other proximity types, such as cognitive proximity, which can increase over time for engineering firms and research organisations that are socially and geographically close (Steinmo & Rasmussen, 2016). Geographical proximity has also been found to be more important to collaborations between organisations with different institutional backgrounds than to organisations of the same type (Ponds *et al.*, 2007).

Finally, and in terms of sectoral characteristics, a distinction can be made between analytical and synthetic knowledge bases (Asheim & Gertler, 2005; Asheim & Coenen, 2005; Asheim *et al.*, 2011). An analytical knowledge base is characteristic of industries where scientific knowledge is important and knowledge creation is based on formal models, codified science and rational processes (e.g., biotechnology) (Asheim & Gertler, 2005). Knowledge tends to be codified and then transferred from R&D organisations to enterprises through formal R&D cooperation, which typically leads to radical innovation (Asheim & Coenen, 2005). This is because, in biotechnology, university-generated knowledge is often generic and capable of creating a broad range

of applications (Salavisa *et al.*, 2012). When innovation builds on analytical knowledge, R&D and scientific research gain prominence and university-industry connections become more important and frequent (Asheim, 2007). As knowledge is often codified, it can be exchanged over long distances after the initial explorative stages of research (Mattes, 2012; Martin, 2013).

A synthetic knowledge base prevails in settings where there is tacit knowledge, and the application of a novel combination of existing knowledge dominates (Asheim & Gertler, 2005). This occurs in software and computing services that are based more on engineering than science (Salavisa *et al.*, 2012; Weterings & Ponds, 2009). In these cases, recombining knowledge that has been drawn from suppliers or service firms usually leads to incremental innovation (Asheim & Coenen, 2005). Although developments take place at a rapid pace in software, this generates a more limited scope of entrepreneurial opportunity (Salavisa *et al.*, 2012). University-industry connections remain relevant to applied research and development (Asheim & Gertler, 2005). Nevertheless, networks are primarily created between suppliers and customers and within communities of practice (Martin, 2013). Firms with a synthetic knowledge base require more specific expertise, craft and practical skill, which are difficult to exchange across geographical distances (Asheim *et al.*, 2007). For these reasons, they tend to be less involved in international cooperation and more focused on local issues (Coenen et al., 2006; Herstad *et al.*, 2014; Martin, 2013).

2.2 Structural factors

Social network analysis focuses on the structure and evolution of interorganisational interaction and the flow of information, knowledge and other resources (Ter Wal & Boschma, 2009). Because actors are organised in networks of nodes that are connected through structured relationships (Granovetter, 1973; Krackhardt, 1992), social network analysis enables different network structures and the role that actors play in those networks to be explored (Prell, 2012). Brokers transfer knowledge between actors who are not directly linked (Nooteboom, 2003). They can also recombine and exploit the knowledge that they draw from the various actors benefitting thus from their intermediary position (Hargadon & Sutton, 1997). Knowledge brokering involves both the transfer and conversion of knowledge (Chen *et al.*, 2015) and is indicative of the flow of knowledge (Kauffeld-Monz & Fritsch, 2013). In terms of geography and brokerage types, Balachandran and Hernandez (2018) found that while actors in domestic triads (three

connected actors) can affect the productivity of innovation, actors in foreign triads are more likely to strongly influence the radical nature of innovation.

Networks in industries that are based in analytical knowledge have been found to remain weakly embedded in their host regions (Liu *et al.*, 2013). In sectors that rely on analytical knowledge bases, patents are more frequently used to protect intellectual property (Ter Wal & Boschma, 2009). In addition, the use of this type of protection has been found to increase firms' willingness to collaborate at a distance with globally-dispersed partners (Herstad *et al.*, 2014). Although formal firm networks are likely to be larger, more connected, less dense, more centralised and more clustered, informal firm networks are often organised around universities that act as informal knowledge providers (Salavisa *et al.*, 2012). Chen *et al.* (2015) revealed that in cases of brokerage, policy-induced intermediaries did not fulfil their brokerage roles in the Taiwanese biopharmaceutical sector. They also argued that research organisations and firms should play more active roles in brokering information.

Firms that rely on synthetic knowledge frequently develop close connections in their networks through production, suppliers and clients at the regional level (Liu *et al.* 2013). This means that they also remain less involved in international collaboration (Herstad *et al.*, 2014). Although formal firm networks have been found to be significantly fragmented and corporate, informal networks can be absent altogether or only present with other central firms (Salavisa *et al.*, 2012). Kauffeld-Monz and Fritsch (2013) concluded that for regional innovation networks in Germany, public research organisations were important for the exchange of interregional knowledge, especially in lagging regions without larger firms. Kim *et al.* (2018) advanced a similar argument for networks within South Korea.

2.3 Analytical framework of the study

The analytical framework for the study postulates that biotechnology and software networks differ in terms of their origin, reliance on different knowledge bases, the core ideas behind their innovations, their geographical compositions and their strategic actors and network structures (Table 1). While biotechnology originated in university labs, the software industry has emerged alongside with the development of computer business and increased use of personal computers.

For biotechnology networks, their analytical knowledge bases involve scientific knowledge that is created through formal deductive processes. For

software networks, their synthetic knowledge bases require more applied knowledge that is often generated through inductive processes. While sectors with analytical knowledge bases produce more radical innovations, industries with synthetic knowledge bases make more incremental advancements.

Table 1. Analytical framework of the study

	Biotechnology	Software
Origin	University labs	Computer business, personal computers
Dominating knowledge base	Analytical, i.e. scientific knowledge often based on deductive processes and formal models	Synthetic, i.e., applied, problem-related knowledge (engineering), often created through inductive processes
Core idea of innovation	Creation of new knowledge leading more often to radical innovation	Application or recombination of existing knowledge leading mainly to incremental innovation
Geographical composition	Networks weakly embedded in the host region due to dominance of codified knowledge resulting from documentation in patents and publications	Close linkages develop with producers, suppliers and clients due to dominance of tacit knowledge resulting from more concrete knowhow, craft and practical skill
Strategic actors	Research collaboration between firms (R&D department) and research organisations, learning as a top-down process, firms' networks organised around universities	Interactive learning of enterprises with other firms, clients and suppliers, learning as a bottom-up process, firms' networks are corporate-based, universities absent or present with central firms
Network structure, incl. brokerage	Networks are larger, more connected, less dense, more centralised and more clustered, brokers are mainly higher education and research organisations	Networks are more fragmented, brokers are both higher education and research organisations and larger enterprises

Source: Compiled by the authors based on Asheim & Coenen, 2005; Mattes, 2012; Salavisa *et al*., 2012; Liu *et al*., 2013; Steinmo & Rasmussen, 2016

Networks with analytical knowledge bases are often international, as the more codified nature of knowledge allows it to be transferred over greater distances. In networks with synthetic knowledge bases, spatial closeness is essential because the more tacit nature of this type of knowledge requires

face-to-face contact for it to be exchanged. Learning tends to occur as a top-down process in sectors with analytical knowledge bases, and higher education and research organisations play a central role in its facilitation. In sectors with synthetic knowledge bases, learning is more of a bottom-up process, where central firms are as important as the universities and communities of practice that emerge. While, in the former case, networks tend to be larger, more connected and centralised, in the latter case they are often more fragmented.

3. Methodology

This study is placed within the context of the Baltic States: Estonia, Latvia and Lithuania. Because these countries are located at the Eastern border of the EU, they are considered to be at the periphery of innovation (Eder, 2019). According to the European Innovation Scoreboard, while Estonia is a strong innovator, Latvia and Lithuania are moderate innovators that perform below the EU average for innovation (European Innovation Scoreboard, 2019). According to the Global Innovation Index, within the wider region of the Baltic Sea, the Baltic States (especially Latvia and Estonia) are characterised by lower levels of university-industry research collaboration (Murashova & Loginova, 2017).

The three countries share a similar history in that they regained independence in the early 1990s, joined the EU in 2004 and adopted the euro after 2010. Nonetheless, the countries differ demographically and in terms of their economic development (Table 2). Estonia is the smallest of the countries by area and population, but it has the highest GDP per capita and the lowest unemployment rate. The R&D intensity, i.e., the expenditure on R&D as a percentage of GDP, is the highest in Estonia, followed by Lithuania and Latvia. In Estonia, the service sector dominates more than in the other countries, but the GPD of the country's ICT sector is equal to that of Latvia. Estonia has the lowest number of higher education institutions (and the smallest population), but it has more R&D personnel, patent applications and a higher h-index than the other countries. While in 2006, publications by Estonian authors were referred to 20% less than 50% of the publications from the leading countries in the world, by mid-2018, the rate of reference for Estonian publications had grown to 40% more references than in the comparison group (Lauk & Allik, 2018). Software and biotechnology were

selected for the present analysis, as these are the smart specialisation areas of the Baltic States and reflect the current strengths and future potential of these economies (Smart Specialisation, 2017a; 2017b; 2017c).

Table 2. Key data for the Baltic States

	Estonia	Latvia	Lithuania
Population[a]	1,305,960	1,924,970	2,872,427
Area (sq. miles)[b]	17,462	25,640	26,080
GDP per capita[c]	19,704.7	15,594.3	16,680.7
R&D intensity[d]	1.4	0.6	0.9
Unemployment (%)[e]	5.8	8.7	7.1
Labour force by sector (%)[f] agriculture industry services	 2.7 20.5 76.8	 7.7 24.1 68.1	 9.1 25.2 65.8
ICT sector in GDP (%)[g]	4.2	4.2	2.9
No. of HEIs[h]	20	24	47
No. of papers[i]	3055	2249	3741
H-index[j]	38	22	26
R&D personnel (FTE, % of labour force)[k]	0.8771	0.535	0.7623
No. of patent applications[l]	36.31	22.26	21.57

Source: compiled by the authors

Note:

[a] Population in 2018, http://worldpopulationreview.com/;
[b] https://www.ucis.pitt.edu/crees/sites/default/files/images/documents/Baltics.pdf;
[c] GDP per capita in 2017 (current US dollars), https://data.worldbank.org/, Eurostat;
[d] R&D intensity (expenditure on R&D as a percentage of GDP) in 2018, http://www.oecd.org/sti/msti.htm;
[e] Unemployment rate 2017, Eurostat;
[f] https://www.cia.gov/library/publications/the-world-factbook/;
[g] ICT sector in GDP in 2015, Eurostat;
[h] European Commission;
[i, j] Web of Science in 2017;
[k] R&D personnel in 2016, Eurostat;
[l] Patent applications to the European patent office in 2017, Eurostat.

More specifically, the study focuses on EU-funded research projects in which organisations from the Baltic States have participated. The study is conducted in the context of EU research and innovation policy that has carried the three primary aims that follow: open innovation, open science

and open access to the world (European Commission, 2016). These policy objectives have been supported by EU programmes for research and innovation as tools for managing the implementation of community research initiatives. The EU began its involvement in research activities in the 1970s. At the start of the 1980s, the FP for research was established as a tool for managing the implementation of community research initiatives. Historically, FP1 was launched in 1983, followed by FP2 in 1987, FP3 in 1990, FP4 in 1994, FP5 in 1998, FP6 in 2002, FP7 in 2006 and FP8 in 2013, which was renamed Horizon 2020 (Reillon, 2017). Estonia, Latvia and Lithuania began to participate in the FPs in the 1990s in a limited manner and on a project-by-project basis. They became full members of the EU and FPs in 2004 (Moedas & Smits, 2015).

This study performs a social network analysis—an approach with a conceptual, methodological and analytical toolkit (Prell, 2012). It suits the purposes of the current article by allowing the structure of social action (i.e., relational data) to be analysed and by facilitating an understanding of the density and texture of social networks (Scott, 2013).

Data about research projects and participating organisations from 1995 to 2016 originated from the European Commission's CORDIS database, which is a public repository containing information on all EU-funded research projects and their results (CORDIS, 2020). The data were inserted into MS Excel as a list of projects and participating organisations, and unique pairs of all organisations were generated within each project. The data were further analysed using UCINET, a general-purpose computer programme for network analysis that enables the calculation of various network measures, such as density, degree, betweenness and clustering (Borgatti *et al.*, 2002). Single-mode (1-mode) square matrices were used with as many rows and columns as there were actors (organisations) in the data set, and the scores in the cells of the matrix recorded information about the ties between each pair of actors (Hanneman & Riddle, 2005). Binary matrices were used. The cell scores were equal to 1 when the organisations had participated in the same project and equal to 0 when they had not. The ties in the matrices were undirected. In addition, the matrices were symmetrical as a mutual tie was assumed to exist between organisation pairs that had taken part in the same project.

The patterns were visualised with Netdraw, which enabled a graphic representation of the networks that included their relations and attributes (Borgatti *et al.*, 2002). To understand the social processes that formed the tie

structures in a given network (Hanneman & Riddle, 2005), node attributes were assigned to the organisations. Based on the earlier literature review, three types of attributes were used: organisation type, location and total normalised brokerage scores. Following the classifications that had been collected from the CORDIS database, organisation type included higher education and research organisations, private for-profit entities, public bodies and others (e.g., NGOs and foundations). It enabled the participation and brokerage of different types of organisations in biotechnology and software networks to be explored. Location was assigned according to the UN geographical division of countries[1]: Eastern Europe, Northern Europe, Western Europe, Southern Europe and outside of Europe (with Estonia, Latvia and Lithuania included in the designation 'Eastern Europe') (UN, 2020). This enabled the brokerage of different types of organisations within their own regions and between regions to be observed. The total normalised brokerage scores were calculated with UCINET.

The following network metrics were calculated with UCINET and used in the current paper to analyse the density and texture of the networks:

- Density: levels of linkage among actors, i.e. the proportion of the maximum possible number of ties (Scott, 2013).
- Components: connected subgraphs of actors, wherein all actors are connected through ties, but there are no ties to actors outside a given component (Scott, 2013).
- Clustering coefficient: a clustering measure (i.e., the extent to which actors form small groups, wherein many actors are present and only a few actors are connected through different clusters with each other) (Kunegis, 2017).
- Degree centrality: involvement in the network (i.e., the number of immediate contacts an actor has in a network) without considering the directions of each tie (Prell, 2012).
- Betweenness centrality: a distance-based measure that includes indirect links within the network (Kauffeld-Monz & Fritsch, 2013). The measure looks at the levels of a complete network and how often

[1] Eastern Europe: Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia and Ukraine.
Northern Europe: Denmark, Finland, Iceland, Norway, Sweden and United Kingdom.
Western Europe: Austria, Belgium, France, Germany, Luxembourg, Netherlands and Switzerland
Southern Europe: Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, Serbia, Slovenia and Spain.
Outside Europe: the remaining countries.

an actor is placed between two other actors (i.e., how often an actor lies on the geodesic distance (shortest path) that connects two other actors) (Prell, 2012). It also indicates potential control over the flow of information (Prell, 2012) and the ability to absorb that information (Owen-Smith & Powell, 2004).

- Normalised brokerage: a type of analysis that involves ego network data and focuses on the number of instances that an ego brokers between two unconnected others (Prell, 2012). Raw brokerage scores are divided by the expected values given group sizes to analyse which roles of actors are significant, as these occur more frequently than expected (Hanneman & Riddle, 2005).

Since the data this study uses are based on archival data instead of sociometric questionnaires, the ties between actors are treated as undirected. Therefore, Gould and Fernandez's (1989) brokerage roles were modified to include the following:

- Coordinator: an actor that connects two other actors in its own group (i.e., actors from the same region).
- Gatekeeper: an actor that connects a member of its own group with an outsider (i.e., one actor from the same region with an actor from another region).
- Consultant: an actor that connects two members of a group from a region that is not its own (i.e., two actors from another region).
- Liaison: an actor that connects members of two different groups from regions that are not its own (i.e., two actors from two different regions) (Lissoni, 2010).

The Kruskal-Wallis H test was used to examine the differences between the total normalised brokerage roles of coordinator, gatekeeper, consultant and liaison (dependent variables) and the types of organisations (independent variables). The brokerage roles were calculated according to the actors' locations (using location as a grouping variable) in order to study the brokerage of different organisation types across the geographical distances of different regions. The Kruskal-Wallis H test is a rank-based nonparametric test, which indicates "statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable" (Laerd Statistics, 2018). It is also used as the assumption of equality of group variances is violated (Morgan *et al.*, 2020). Post-hoc comparisons were undertaken to determine which of the factor's values contributed most to the explanation of the dependent variables. Post-

hoc Tamhane T2 test was used because of the unequal variance and sample size (Shingala & Rajyaguru, 2015).

The sample consisted of 407 projects (168 in biotechnology and 238 in software) (Table 3). For the purposes of the analysis, the projects were divided into three time periods in accordance with the start and end dates of the various FPs. These included 1995–2003 for FP4, FP5, IC-INTAS and IS-ECONTENT; 2003–2007 for FP6, IC-INTAS and IS-ECONTENT; and 2007–2016 for FP7, H2020 and CIP (IC-INTAS, 2014; IS-ECONTENT, 2001; CIP, 2015).

Table 3. Network metrics for biotechnology and software networks

Network parameters	Components of measures	Biotechnology			Software		
		1995–2003 (FP4, FP5)	2003–2007 (FP6)	2007–2016, (FP7, H2020)	1995–2003 (FP4, FP5)	2003–2007 (FP6)	2007–2016, (FP7, H2020)
Size	No. of projects	36	113	20	96	115	27
	No. of countries	34	64	48	49	67	61
	No. of actors	228	1,221	280	921	1,316	488
	Actors per project (average)	8.5	17.1	18.2	12.1	17.1	22.7
	No. of ties	3,466	68,374	6,490	33,290	48,794	29,094
	No. of components	1	1	2	16	4	2
	Size of largest component	228	1,221	272	805	1,292	478
Cohesion	Density (overall)	0.07 (0.3)	0.05 (0.2)	0.08 (0.3)	0.04 (0.2)	0.03 (0.2)	0.1 (0.3)
Centrality of actors	Degree (average)	15	56	23	36	37	60
	Betweenness (average)	219 (358)	929 (3,501)	387 (1,732)	596 (2,657)	1047 (4,756)	286 (1,060)
Cohesive subgroups	Clustering coefficient (%)	91	90	93	95	90	95

Table 4. Actors and brokers in biotechnology and software networks

Network parameters	Components of measures	Biotechnology			Software		
		1995–2003 (FP4, FP5)	2003–2007 (FP6)	2007–2016, (FP7, H2020)	1995–2003 (FP4, FP5)	2003–2007 (FP6)	2007–2016, (FP7, H2020)
Composition – types of organisations (%)	Higher education and research	61.8	44.9	44.3	39.7	35.6	54.5
	Private for-profit entities	15.8	30.5	26.8	36.4	38.1	20.1
	Public bodies	7.5	7.8	22.1	11.2	14.4	16.4
	Other (NGOs, etc.)	14.9	16.8	6.8	12.7	11.9	9.0
Composition – location (%)	Eastern Europe	23.3	20.6	19.6	23.6	20.2	16.2
	Northern Europe	26.8	22.4	20.4	21.2	20.1	19.9
	Western Europe	30.7	32.1	30.7	27.8	31.1	31.8
	Southern Europe	17.1	18.8	23.2	24.5	22.2	26.0
	Outside of Europe	2.2	6.1	6.1	2.9	6.5	6.2
Brokers – types of organisations (%)	Higher education and research	58.7	68.8	20.3	76.4	57.7	77.8
	Private for-profit entities	4.8	11.6	1.7	8.9	21.1	4.2
	Public bodies	17.5	8.1	59.3	7.3	12.1	12.5
	Other (NGOs, etc.)	19.0	11.6	1.7	7.3	9.1	5.6
Brokers – location (%)	Eastern Europe	35.0	20.4	20.3	24.4	21.5	19.4
	Northern Europe	31.7	24.2	22.0	22.0	20.8	20.8
	Western Europe	20.6	33.3	37.3	30.9	27.2	36.1
	Southern Europe	11.1	17.2	15.3	20.3	26.5	19.4
	Outside of Europe	1.6	4.9	5.1	2.4	4.0	4.2

In biotechnology, there were 228, 1221 and 280 actors in the three time periods. The average degree was the highest during the second period (FP6), with a single actor having an average of 56 direct ties (Table 3). While the overall density was the highest during the first (FP4 and FP5) and third periods (FP7 and H2020), the average betweenness was also the lowest during these periods, indicating fewer structural holes in the network. The biotechnology network was heavily clustered during each period.

In software, there were 921, 1,316 and 488 participant organisations across the three periods. Participation in the software projects was more active than in biotechnology, especially during the first two periods (FP4, FP5 and FP6). The degree was the highest during the third period (FP7, H2020), with a single actor having an average of 60 ties. Although the overall density of the network was at its highest in the third period (FP7 and H2020), the average betweenness was at its lowest during this period, indicating fewer structural holes. Like in biotechnology, the networks in the three periods were highly clustered.

Most of the actors in biotechnology were located in Western Europe, followed by Northern and Eastern Europe (Table 4). Higher education and research organisations were the most prevalent types of actors, followed by enterprises, NGOs and public bodies. In software, the overall division of organisations between regions was different from biotechnology due to the larger number of actors from Southern Europe, but similar regarding the participation of Western and Northern European organisations. Enterprises were more represented in software, except in the third period.

This study was limited by the uneven distribution between the networks' projects and actors and the sectors and periods that led to the comparison of networks of different sizes. This influenced some of the networks' characteristics. As an example, density tended to be higher in smaller networks because it was more difficult for the actors to be connected with a larger proportion of other actors from larger networks.

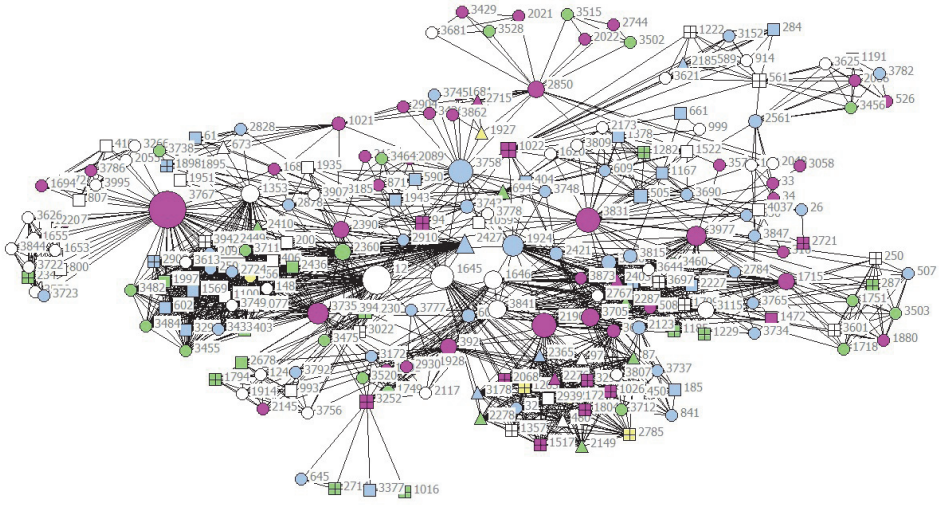
The use of archival CORDIS data limited the number of variables that were used in this study. Because the project participants' organisation types and locations were recorded in the database, these were also used in the present study. Regardless, it is not uncommon for studies on collaborative networks to use only two variables. To illustrate, Ponds *et al.* (2007) used institutional and geographical proximity to explore the extent to which cooperation between different types of organisations was more geographically localised than cooperation between similar organisations.

4. Results

4.1 Brokers in the biotechnology network

Brokerage, or the extent to which organisations connect otherwise unconnected pairs of actors, has varied across different periods of time. During the first (FP4 and FP5) and second (FP6) of this study's research periods, the actors with the highest brokerage scores were higher education and research organisations from Eastern and Western Europe and Western and Northern Europe, respectively. By comparison, the actors with the highest brokerage scores during the third researched period (FP7 and H2020) included public bodies from Western and Northern Europe (Figs. 1–3). Moreover, Eastern European NGOs were more active as brokers during the first period (FP4 and FP5), and Western and Northern European NGOs were more active during the second period (FP6). Enterprises were the least active brokers amongst the other types of organisations, and the firms with the highest brokerage scores originated from Northern and Western Europe during every period. Furthermore, enterprises from Eastern Europe did not act as brokers at all during the first (FP4 and FP5) and third periods (FP7 and H2020).

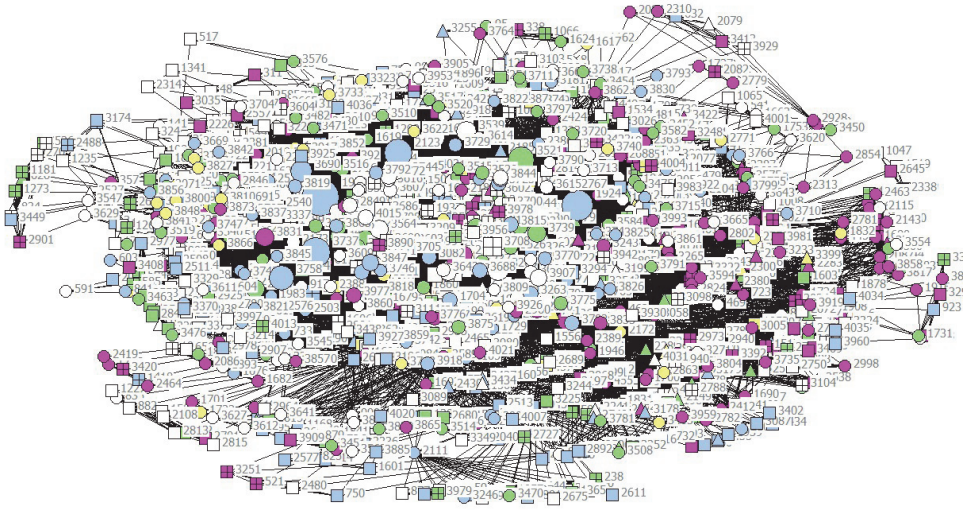
Figure 1. Biotechnology network 1995–2003 (FP4, FP5) (N = 228).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure01.jpg

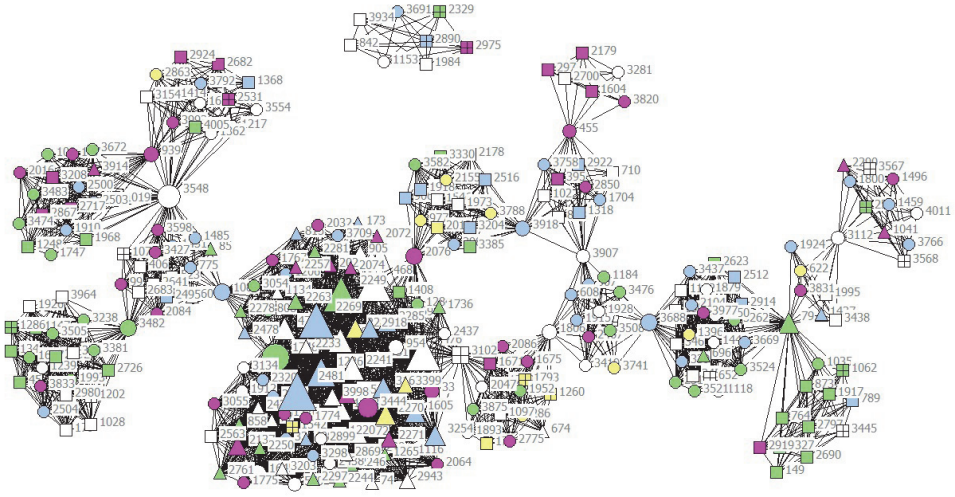
Figure 2. Biotechnology network 2003–2007 (FP6) (N = 1221).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure02.jpg

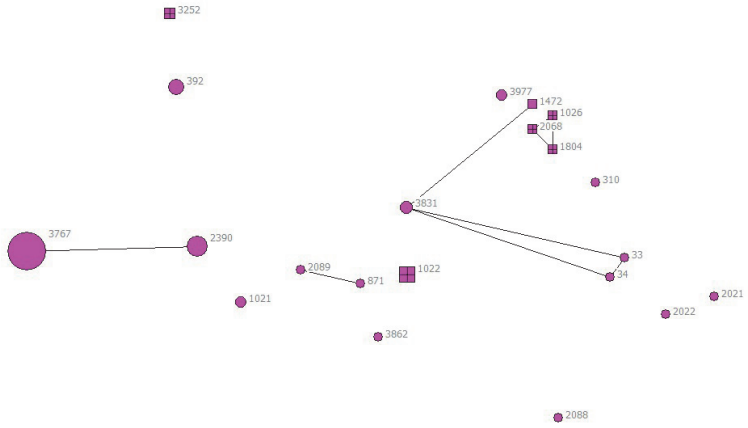
Figure 3. Biotechnology network 2007–2016 (FP7, H2020) (N = 280).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure03.jpg

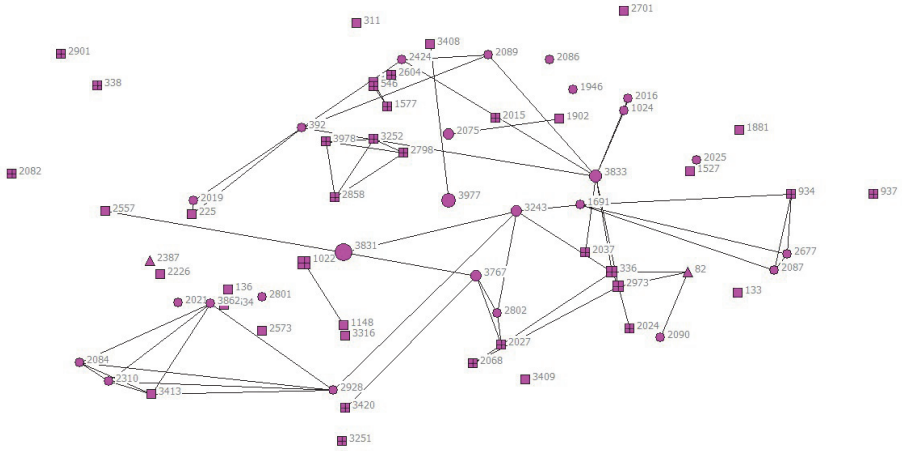
Figure 4. Baltic States actors in biotechnology network 1995–2003 (FP7, H2020) (N = 21).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure04.jpg

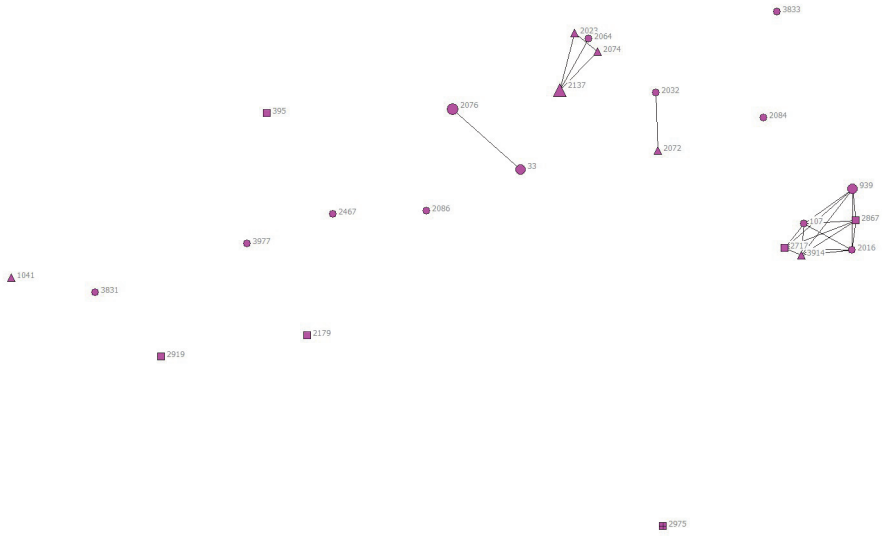
Figure 5. Baltic States actors in biotechnology network 2003–2007 (FP7, H2020) (N = 68).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure05.jpg

Figure 6. Baltic States actors in biotechnology network 2007–2016 (FP7, H2020) (N = 25).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at https://www.ies.ee/tjes/vol10/no1/kuttim/Figure06.jpg

The organisations from the Baltic States that acted as brokers were primarily universities or research institutes (Figs. 4–6). The University of Latvia (Latvia), Estonian Biocentre (now merged with the University of Tartu) (Estonia), Vilnius University (Lithuania) and the University of Tartu (Estonia) had the highest brokerage scores in the first (FP4 and FP5) and second periods (FP6). The University of Technology of Kaunas (Lithuania) and Tallinn University of Technology (Estonia) also had high brokerage scores in the second period. Some of the NGOs and public bodies acted as brokers during all three periods, and only one enterprise from each of the Baltic States acted as a broker during the second period (FP6).

The results from the Kruskal-Wallis H test indicated that there was, in biotechnology, a statistically significant difference in brokerage scores for all four brokerage roles (i.e., coordinator, gatekeeper, consultant and liaison) for the different organisation types during all three time periods (Appendices 1–3). The post-hoc Tamhane T2 test showed that higher education and research organisations embodied the roles of gatekeeper and liaison more

often than enterprises during the first period (FP4 and FP5) and assumed all four roles during the second period (FP6). Public bodies acted as consultants more often than enterprises in the first period and as gatekeepers and liaisons during the second period. The third period (FP7 and H2020) differed from the earlier periods in that public bodies acted as gatekeepers, consultants and liaisons more often than the other organisation types (i.e., NGOs, enterprises and higher education and research organisations).

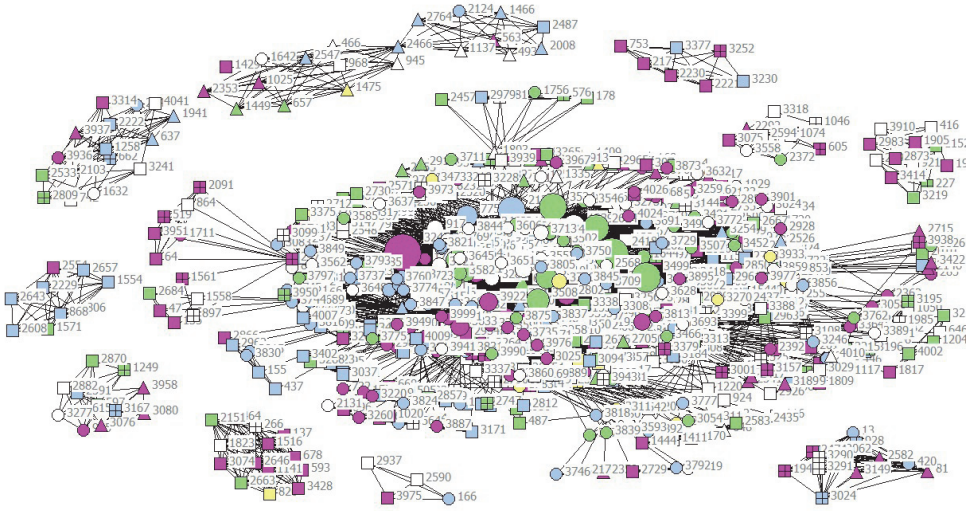
Moreover, the first two periods (FP4 and FP5; FP6) were similar in that universities and research organisations frequently acted as brokers. In the third period (FP7 and H2020), public bodies held strategic positions in the networks and in connecting other actors. Higher education and research organisations often brokered within their regions and across different regions (acting as coordinators, gatekeepers, consultants and liaisons), and public bodies frequently brokered between regions (acting as gatekeepers, consultants and liaisons). During each period, enterprises acted as brokers the least and were underrepresented when compared to the proportion of the enterprises in the overall biotechnology network (Table 4).

4.2. Brokers in software network

In the software network, the actors with the highest brokerage scores were primarily higher education and research organisations from Western and Southern Europe during all periods. In addition, higher education and research organisations from Eastern Europe achieved the highest brokerage scores during the third period (FP7 and H2020) (Figs. 7–9). Enterprises in software had higher brokerage scores than enterprises in biotechnology, especially during the second period (FP6), and primarily originated from Western Europe. Public bodies from Western Europe, Southern Europe and outside of Europe were more active during the second (FP6) and third periods (FP7 and H2020), and NGOs from Western Europe were more active in the third period (FP7 and H2020).

Like with biotechnology, the actors from the Baltic States that acted more frequently as brokers were higher education and research organisations (Figs. 10–12). In addition, both classical universities (the University of Latvia, Vilnius University, the University of Tartu) and specialised technical universities had higher brokerage scores during every software period. These technical universities included Tallinn University of Technology (Estonia), the University of Technology of Kaunas (Lithuania), Riga Technical University (Latvia) and Vilnius Gediminas Technical University (Lithuania). Public

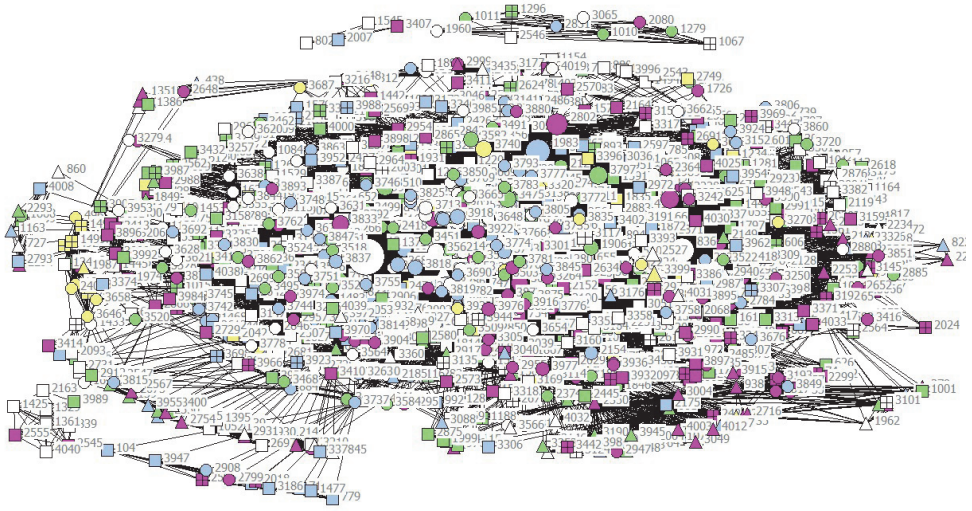
Figure 7. Software network 1995–2003 (FP4, FP5) (N = 921).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure07.jpg

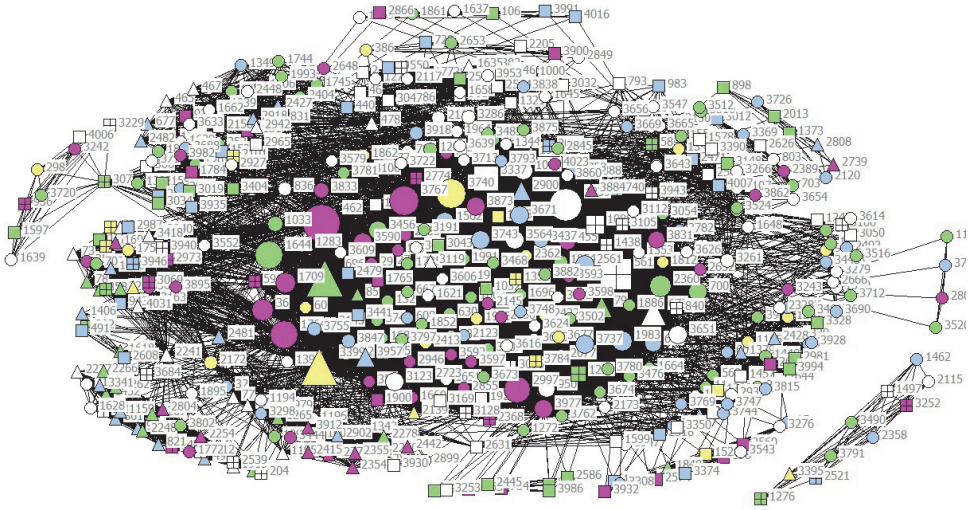
Figure 8. Software network 2003–2007 (FP6) (N = 1316).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure08.jpg

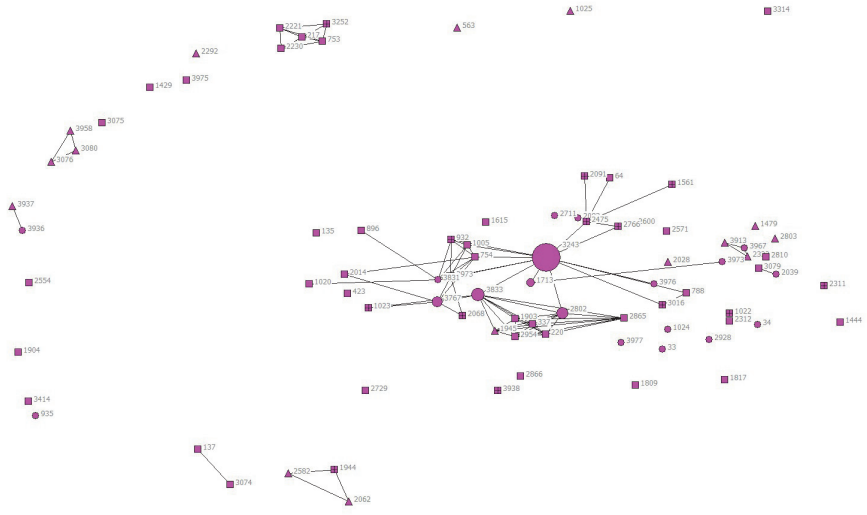
Figure 9. Software network 2007–2016 (FP7, H2020) (N=488).



Note: Red – Eastern Europe, blue – Northern Europe, white – Western Europe, green – Southern Europe, yellow – outside of Europe; circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure09.jpg

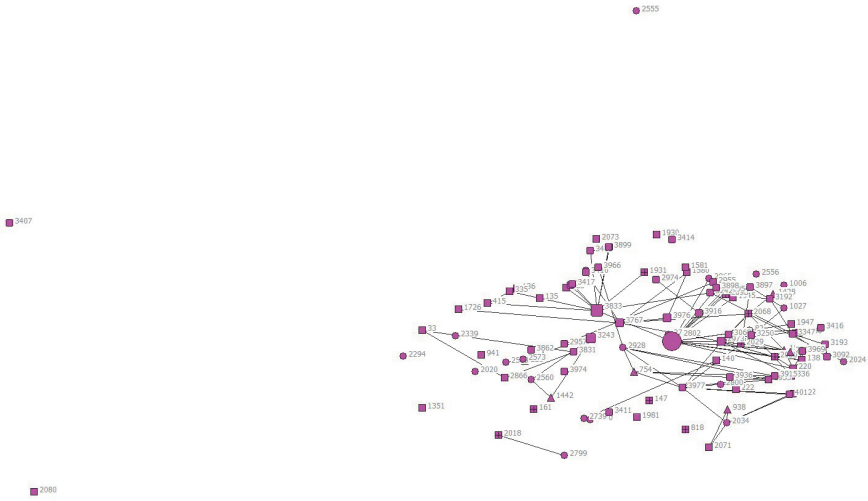
Figure 10. Baltic States actors in software network 1995–2003 (FP7, H2020) (N = 86).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at
https://www.ies.ee/tjes/vol10/no1/kuttim/Figure10.jpg

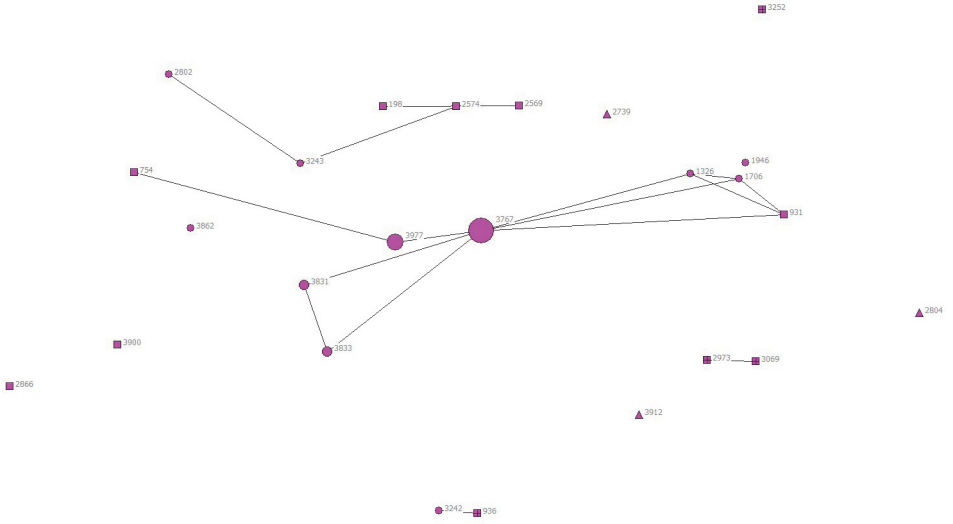
Figure 11. Baltic States actors in software network 2003–2007 (FP7, H2020) (N = 104).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at https://www.ies.ee/tjes/vol10/no1/kuttim/Figure11.jpg

Figure 12. Baltic States actors in software network 2007–2016 (FP7, H2020) (N = 25).



Note: Circle – higher education and research organisations, square – private for-profit, triangle – public bodies, box – NGOs; node size – based on total normalised brokerage scores.

See high-resolution figure in colour online at https://www.ies.ee/tjes/vol10/no1/kuttim/Figure12.jpg

bodies and NGOs acted as brokers during the first two periods (FP4 and FP5; FP6). Only one enterprise from the Baltic States in the first period (FP4 and FP5) and six during the second period (FP6) brokered between other actors.

The between-group comparison that was performed with the Kruskal-Wallis H test indicated that there was also in software a statistically significant difference in brokerage scores between the different organisation types for all four brokerage roles (i.e., coordinator, gatekeeper, consultant, liaison) during all three periods (Appendices 4–6). Unlike biotechnology, the mean brokerage score was at its highest for higher education and research organisations during the entire period of study. The post-hoc Tamhane T2 test revealed that universities and research organisations fulfilled all the brokerage roles more often than enterprises. They also acted more frequently as gatekeepers and liaisons than public bodies or NGOs during the first (FP4 and FP5) and second periods (FP6).

To summarise, software networks were dissimilar from biotechnology networks in that higher education and research organisations held the most strategic positions as brokers during all the three periods. Universities and research organisations also brokered more frequently within their own regions and across different regions, alike. Like with biotechnology, the share of enterprises among the brokers was lower than the proportion of enterprises in the network, especially during the first (FP4 and FP5) and third periods (FP7 and H2020) (Table 4).

5. Discussion

The present study revealed several differences between biotechnology and software networks. Overall, there were more software projects than biotechnology projects during the time period when organisations from the Baltic States participated (1995–2016). In addition, the number of actors and ties between those actors was higher in software projects. While participation started rather modestly in biotechnology, it was much more important in software. The second and third periods were similar in that participation peaked during FP6 and decreased sharply during FP7 and H2020. This can be attributed to the impact of economic crises and the increased share of infrastructural support measures for the Baltic States, both of which decreased the availability for self-financing in organisations and the means of participating in the R&D projects.

The study indicated that there were no significant differences between the biotechnology and software networks in terms of location, as the participation rate of actors from outside of Europe was rather low and the participation rate of actors from Western Europe was highest for both networks. This confirms the assumption by Asheim and Gertler (2005), who stated that the innovation process or industries with analytical and synthetic knowledge base are equally and spatially concentrated. By comparison, these findings contradict assertions from Coenen *et al.* (2006) and Herstad *et al.* (2014), who determined that networks with analytical knowledge bases were more spatially distributed and international. This can be explained by the nature of EU research projects. Indeed, while these projects are not formed upon evolutionary bases and focus on EU countries/actors, they must also adhere to strict qualification criteria and funding rules (Balland, 2012). Autant-Bernard *et al.* (2007) found that the impacts of proximity and network effects do exist at both the European and individual country level, as the actors are more likely to cooperate when they have already collaborated or when they are located closely in the network (i.e., they share close social proximity). The varied participation rates of actors from different countries can also be attributed to their distinct levels of economic development and the balance that individual European regions strike between public and private R&D (Blažek & Kadlec, 2019).

Different types of actors participated in the biotechnology and software networks. While higher education and research organisations dominated in biotechnology, the distribution of participation of organisations was less uneven in software, indicating that software firms contribute to R&D and the generation of new knowledge. In biotechnology, more universities fulfilled this role (Asheim & Coenen, 2005). The lower participation rates from biotechnology firms can also be attributed to other sectoral characteristics, since the industry is characterised by its high complexity, uncertainty and long product-service development timeframes (Connected Health, 2015). This partially confirms Salavisa *et al.*'s findings (2012), which argued that although biotechnology networks were more connected, centralised and clustered, software networks were considerably more fragmented and more often centred around enterprises.

While enterprises were active participants in the studied projects, the central brokerage roles were primarily adopted by education and research organisations for both biotechnology and software. This afforded them advantages, such as access to information, control over the flow of knowledge and the ability to join different parts of the network, and disadvantages,

such as the burden and responsibility to connect different segments of the network (Prell, 2012). Public bodies most frequently acted as brokers in biotechnology due to their direct involvement in the sector. Biotechnology is a field that originated in university labs, and has been supported substantially by governmental investments (Owen-Smith & Powell, 2004). The less central role of brokerage does not exclude enterprises from initiating research projects based on their needs or from assembling partners with the required competencies, as there were four such enterprises in software (but none in biotechnology) from the Baltic States.

Organisations can fulfil several brokerage roles—coordinator, gatekeeper, consultant and liaison—and can broker solely within their own regions or across several regions. Higher education and research organisations, and in addition, public bodies in biotechnology, have most often acted as gatekeepers, consultants and liaisons who broker between actors from various regions. This indicates that their networks have a higher geographical reach and confirms the importance of research organisations in acquiring technology from abroad to contribute to local capabilities (Chen *et al.*, 2015). It also highlights the sector-specific role of public bodies as brokers in biotechnology. The centrality of higher education and research organisations in a small non-advanced country setting, which is often outside the major innovative clusters, implies that the gap between globally successful universities and global science is smaller than in the case of industry. Nonetheless, the strength of local science and the connectedness of international scientific networks also allows enterprises to access distant technological mechanisms (Fontes, 2005).

This study highlights the sectoral differences in brokerage as in biotechnology, in addition to higher education and research organisations, also public bodies were able to connect otherwise unconnected actors. This confirms that while the central brokerage roles of higher education and research organisations are often not sector-specific (Kauffeld-Monz & Fritsch, 2013; Kim *et al.*, 2018), that of public bodies is, being characteristic of biotechnology.

6. Conclusions

This article aimed to further develop an understanding of the institutional and structural features of knowledge networks by relating the brokerage roles of actors to the organisational types and locations of biotechnology and software networks. Two research questions were posed: (1) what characterises the knowledge brokers of biotechnology and software networks in terms of organisational type and location; and (2) to what extent do the brokers who represent different organisational types fulfil different brokerage roles (i.e., coordinators, gatekeepers, consultants or liaisons)?

The study's results indicated that while the geographical division of brokers corresponded to the overall proportion of actors from different regions, the division by organisational type did not. Higher education and research organisations were overrepresented as brokers in both sectors, public bodies were overrepresented in biotechnology and enterprises were underrepresented in both fields. This could mean that the enterprises that were analysed in this study acted less as the coordinators of projects and that the projects they led had fewer participants. Because it is costly, enterprises might therefore be interested in being participants only, rather than coordinators, in research projects that fall under their areas of expertise. They might also consider only pursuing problems that can be solved with specific R&D and that contribute to the development of their products and services regardless of sector. On the other hand, higher education and research organisations carry broader levels of expertise and may be interested in projects also for scientific reasons without direct or practical outcomes. Previous studies have determined that enterprises primarily develop an absorptive capacity within a fairly narrow sectoral setting, as university units often need to operate in a large number of distinct disciplinary and sectoral domains (Kenney & Patten, 2009). Because acquiring and using more distant knowledge requires a deliberate effort of creating absorptive capacity, the absorptive capacity itself is cumulative by nature and restricts the activities of enterprises to specific domains (Cohen & Levinthal, 1990).

This study's results additionally revealed that higher education and research organisations, and in biotechnology also public bodies, tended to broker more frequently across different regions. Because project-based funding is important for research at universities and research institutions, and EU research projects can involve a large number of participants (e.g., 176 organisations in European Leukemianet; 142 in EGI-InSPIRE), higher

education and research organisations hold strategic positions within knowledge networks. The role that public bodies play is sector-specific, as biotechnology is dependent upon public sector investments. At the same time, enterprises vary in their capacity to build international connections. The costs of accessing and translating knowledge in global networks tend to be smaller for large, domestic and international companies and academic spin-out SMEs, than for established SMEs because of the effects of size in larger companies, specialisation and economies of scale in R&D (Fransman, 2008). It follows that the pool of enterprises capable of participating in global knowledge networks is limited. The EU projects represent a case where enterprises can benefit from universities' wider participation, but as project coordinators, the different types of organisations also compete for limited research funding.

This study contributed to the theoretical, empirical and practical analysis of sectoral knowledge networks. First, it developed further the understanding of the institutional and structural features of knowledge networks by focusing on brokers and their brokerage roles. It then related these to specific organisation types and the actors' locations within the two studied sectors. The results indicated that brokers in the EU research projects, where organisations from the Baltic States participated, were primarily located in Western and Northern Europe and contained greater numbers of higher education and research organisations and public bodies in networks with analytical knowledge bases (biotechnology). In networks with synthetic knowledge bases (software), the brokers most frequently originated in Western and Southern Europe and primarily included higher education and research organisations. The study also revealed that higher education and research organisations, in addition to public bodies in relation to biotechnology, had greater geographical reach, as they brokered more frequently between organisations from different regions than the other types of actors.

Second, the paper included additional empirical context to the study of sectoral knowledge networks, by looking at research projects in biotechnology and software where Baltic actors have participated. It explored the evolution of knowledge networks and actors who were initially at a disadvantage regarding older Member States, with a longer period of participation in EU research projects.

Third, the study provided information for organisations applying for EU research projects. The results illustrated the benefits of collaborating

with higher education and research organisations for local enterprises, in addition to the benefits of teaming with public bodies for biotechnology networks, by increasing access to the flow of knowledge through the expansion of geographical reach. With the assistance of more well-connected organisations, enterprises can also broaden their access to international flow of knowledge.

Future studies might focus on developing these data into a 2-mode network, connecting actors to projects and projects to specific funding periods (from FP4 to H2020) that could enable the dynamics of actors' participation over time to be assessed. This would allow researchers to monitor the extent to which the same actors have participated in different projects during the same and over consecutive periods. Subsequent studies could also combine social network analysis with qualitative interviews to better understand the reasons behind the networking patterns that have been observed in collaborative research projects of biotechnology and software.

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Appendices

Appendix 1. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in biotechnology 1995-2003 (FP4, FP5).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordinator	Higher education and research	141	120.50	7.33	3	0.061
	Private for-profit entities	36	101.39			
	Public bodies	17	106.38			
	Other (NGOs. etc.)	34	107.57			
Gatekeeper	Higher education and research	141	121.30	8.80	3	0.031
	Private for-profit entities	36	98.33			
	Public bodies	17	109.06			
	Other (NGOs. etc.)	34	106.15			
Consultant	Higher education and research	141	110.82	27.59	3	0.000
	Private for-profit entities	36	93.19			
	Public bodies	17	169.18			
	Other (NGOs. etc.)	34	125.00			
Liaison	Higher education and research	141	120.13	7.53	3	0.056
	Private for-profit entities	36	97.13			
	Public bodies	17	113.91			
	Other (NGOs. etc.)	34	109.82			

Appendix 2. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in biotechnology 2003-2007 (FP6).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordinator	Higher education and research	548	686.81	102.00	3	0.000
	Private for-profit entities	373	521.40			
	Public bodies	95	617.29			
	Other (NGOs. etc.)	205	568.46			
Gatekeeper	Higher education and research	548	688.01	99.57	3	0.000
	Private for-profit entities	373	522.39			
	Public bodies	95	616.91			
	Other (NGOs. etc.)	205	563.63			
Consultant	Higher education and research	548	680.36	82.78	3	0.000
	Private for-profit entities	373	529.41			
	Public bodies	95	624.61			
	Other (NGOs. etc.)	205	567.73			
Liaison	Higher education and research	548	684.92	94.68	3	0.000
	Private for-profit entities	373	524.82			
	Public bodies	95	626.82			
	Other (NGOs. etc.)	205	562.90			

Appendix 3. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in biotechnology 2007-2016 (FP7, H2020).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordinator	Higher education and research	124	137.22	43.239	3	0.000
	Private for-profit entities	75	120.10			
	Public bodies	62	176.25			
	Other (NGOs. etc.)	19	125.79			
Gatekeeper	Higher education and research	124	136.33	48.845	3	0.000
	Private for-profit entities	75	119.08			
	Public bodies	62	179.54			
	Other (NGOs. etc.)	19	124.84			
Consultant	Higher education and research	124	135.50	67.398	3	0.000
	Private for-profit entities	75	113.58			
	Public bodies	62	189.95			
	Other (NGOs. etc.)	19	118.05			
Liaison	Higher education and research	124	136.12	51.574	3	0.000
	Private for-profit entities	75	118.63			
	Public bodies	62	180.68			
	Other (NGOs. etc.)	19	124.32			

Appendix 4. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in software 1995-2003 (FP4, FP5).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordinator	Higher education and research	366	513.92	79.19	3	0.000
	Private for-profit entities	335	419.44			
	Public bodies	103	428.79			
	Other (NGOs. etc.)	117	442.83			
Gatekeeper	Higher education and research	366	518.22	83.04	3	0.000
	Private for-profit entities	335	415.51			
	Public bodies	103	435.11			
	Other (NGOs. etc.)	117	435.03			
Consultant	Higher education and research	366	515.48	77.23	3	0.000
	Private for-profit entities	335	416.32			
	Public bodies	103	442.06			
	Other (NGOs. etc.)	117	435.18			
Liaison	Higher education and research	366	518.37	84.16	3	0.000
	Private for-profit entities	335	414.52			
	Public bodies	103	441.43			
	Other (NGOs. etc.)	117	431.86			

Appendix 5. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in software 2003-2007 (FP6).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordi-nator	Higher education and research	468	751.74	90.27	3	0.000
	Private for-profit entities	501	591.93			
	Public bodies	190	624.21			
	Other (NGOs. etc.)	157	634.48			
Gatekeeper	Higher education and research	468	753.02	86.73	3	0.000
	Private for-profit entities	501	592.38			
	Public bodies	190	626.96			
	Other (NGOs. etc.)	157	625.92			
Consultant	Higher education and research	468	752.55	86.24	3	0.000
	Private for-profit entities	501	593.85			
	Public bodies	190	633.84			
	Other (NGOs. etc.)	157	614.26			
Liaison	Higher education and research	468	751.90	86.44	3	0.000
	Private for-profit entities	501	590.91			
	Public bodies	190	639.64			
	Other (NGOs. etc.)	157	618.61			

Appendix 6. Results of Kruskal-Wallis H test for differences in brokerage roles between four groups of organisations in software 2007-2016 (FP7, H2020).

	Type	N	Mean Rank	Chi-Square	df	Sig
Coordinator	Higher education and research	266	258.74	18.54	3	0.000
	Private for-profit entities	98	217.34			
	Public bodies	80	236.95			
	Other (NGOs. etc.)	44	232.64			
Gatekeeper	Higher education and research	266	259.50	19.74	3	0.000
	Private for-profit entities	98	216.60			
	Public bodies	80	235.93			
	Other (NGOs. etc.)	44	231.55			
Consultant	Higher education and research	266	260.16	21.29	3	0.000
	Private for-profit entities	98	215.95			
	Public bodies	80	235.54			
	Other (NGOs. etc.)	44	229.72			
Liaison	Higher education and research	266	260.17	21.63	3	0.000
	Private for-profit entities	98	215.33			
	Public bodies	80	236.14			
	Other (NGOs. etc.)	44	229.93			

Publication IV

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International Knowledge Transfer from University to Industry: A Systematic Literature Review

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Abstract

International knowledge transfer contributes to the competitiveness of enterprises and regions, to the ranking of universities, and to solving common global problems. Based on a systematic literature review, the main purpose of the current study is to explore the channels, motivations, activities and outcomes, and influencing factors of university to industry international knowledge transfer (U-I IKT), and understand how the concept is related to the internationalisation of R&D, innovation systems and higher education. The paper contributes to the existing body of knowledge by creating an integrated framework for understanding U-I IKT. It proposes that U-I IKT can be conceptualised on the basis of two dimensions – on the one hand, as an activity that has distinct channels, motivations, activities and outcomes, and influencing factors. On the other hand, U-I IKT can be seen as a stream of research on its own right, albeit overlapping with other areas of the internationalisation of knowledge transfer, namely the internationalisation of innovation systems, firm R&D activities and higher education institutions.

JEL classification codes: O30
Keywords: international knowledge transfer, university-industry collaboration, cross border, institutional distance

1. Introduction

International knowledge transfer can be seen as a multi-faceted phenomenon. It has become one of the key elements for addressing global problems related to the environment, health, security and economic development. In order to manage these issues, most countries have adopted a number of policies and programmes to promote the international transfer of knowledge and technology. In addition, multi-national corporations (MNCs) have resorted to the internationalisation of their research and development (R&D) for the acquisition of new knowledge from different sources to withstand global competition (Kauppinen, 2012). Consequently, universities are seen as the main producers of 'new knowledge', which contributes to the development, innovation and competitiveness of companies, regions and countries (D'Este and Perkmann, 2011; Huggins et al., 2008; Huggins et al., 2012). Although the engagement of universities with industry has a long tradition, with the need to address global problems, the surge of new policy incentives, the improved regulatory environment and the changing funding base of universities, the number of studies on university-industry relations has increased vastly during the last decade (Perkmann et al., 2013).

Researchers have frequently attempted to synthesize the literature on activities and actors characterizing knowledge transfer (KT) from university to industry (Agrawal, 2001; Perkmann and Walsh, 2007; Rothaermel et al., 2007; Yusof and Jain, 2010; Wahab et al., 2012; Perkmann et al., 2013; Bozeman et al., 2013; Ankrah and Al-Tabbaa, 2015). These reviews have often focused on only one or two aspects of university-industry linkages, for instance, identifying firm/university characteristics, geography of interactions and channels (Agrawal, 2001), developing a taxonomy of university entrepreneurship (Rothaermel et al., 2007; Yusof and Jain, 2010), technology transfer (Wahab et al., 2012), addressing academic engagement antecedents and consequences (Perkmann et al., 2013). In a more comprehensive review paper, Ankrah and Al-Tabbaa (2015) have synthesized the literature on KT under the broad themes of KT processes such as forms, motivations, formation and activities, enablers and inhibitors, and outcomes. However, none of these reviews has focused specifically on the university to industry international knowledge transfer (U-I IKT).

Furthermore, studies on the international dimensions of KT cover a wide range of different streams of research like the internationalisation of university-industry or university-industry-government cooperation (Caloghirou et al., 2001; Tijssen et al., 2009; Shin et al., 2012), the internationalisation of firm R&D (Davis and Meyer, 2004; Dunning and Lundan, 2009; Krishna et al., 2012; Liang et al., 2015), the internationalisation of higher education (Warwick, 2014; Kosmützky and Putty, 2015) and the internationalisation of innovation systems (Carlsson, 2006). These studies have focused mostly on either MNCs, higher education institutions or government as the central actor, but few have explored the interplay between different types of actors located across national boundaries. There is, therefore, a need to understand what is unique about U-I IKT and how it overlaps with other approaches to the internationalisation of KT.

The paper aims to fill these gaps by constructing a framework for understanding university-industry international knowledge transfer. This is achieved by synthesizing the existing literature in order to answer the following research questions: *(i) Are there specific channels, motivations, activities and outcomes, and influencing factors that characterize university-industry international knowledge transfer, and (ii) How does the concept of university-industry international knowledge transfer relate to the internationalisation of R&D, innovation systems and higher education.*

The current paper addresses KT for either academic engagement or commercialisation purposes at the inter-organizational level mainly between individuals who originate from different types of organizations (universities and enterprises, and in some cases universities, enterprises and government), which are situated in different countries. KT from university to industry is understood as comprising academic engagement or knowledge focused research collaborations, and commercial engagement or property focused collaborations (Perkmann et al., 2013; Bozeman et al., 2013). The former activity is pursued for various objectives like expanding the base of knowledge and enhancing the reputation and careers of academics (e.g. collaborative research, contract research, consulting, informal networking), while the latter intends to exploit an academic invention with the objective of financial gain (e.g. patenting, licensing, creating spin-offs).

The paper contributes to the existing body of knowledge by creating an integrated framework for understanding U-I IKT. It proposes that U-I IKT can be conceptualised, on the one hand, as an activity that has distinct channels, motivations, activities and outcomes, and influencing factors, and on the other hand, as a stream of research in its own right that overlaps with other areas of the internationalisation of KT, namely the internationalisation of innovation systems, firm R&D activities and higher education institutions.

The remaining part of the paper is organized as follows. The next section discusses the theoretical issues related to studies of university-industry linkages to construct a conceptual framework to analyze IKT in the context of university-industry collaborations. The subsequent section deals with the methodology adopted for the study. The fourth section presents and discusses the findings of studies on U-I IKT and emerging issues. The last section provides the conclusions, the theoretical contribution of the paper and scope for further research.

2. Overview of main concepts

2.1. University to industry international knowledge transfer

The term knowledge transfer itself is ambiguous (Lockett et al., 2009), as it is used synonymously with a range of related terms, such as 'knowledge dialogue' (Ruddle, 2000), 'knowledge exchange' (Schartinger et al., 2002; Swart and Henneberg, 2007) and 'knowledge translation' (Czarniawska and Sevon, 1996; Savory, 2006). KT between university and enterprises can be seen as a process characterized by multiple channels, motivations, activities and outcomes, and influencing factors (Duan et al., 2010; Ankrah and Al-Tabbaa, 2015). International university to industry KT shares many characteristics with university to industry KT in general.

KT channels can be understood as ways for the transfer of knowledge. University-industry KT consists, on the one hand, of academic engagement or knowledge focused research collaborations, and, on the other hand, of commercial engagement or property focused collaborations (Perkmann et al., 2013; Bozeman et al., 2013). Academic engagement comprises mainly collaborative research, contract research, consulting, informal networking, while commercialisation involves patenting, licensing, creating spin-offs. Some channels are more suitable for certain types of knowledge to be transferred. Explicit knowledge means published research findings, which are codified, formulated and available; but in addition, there is tacit knowledge related to skills and experiences that can only be obtained by face-to-face contact

(Karnani, 2012). Activities that allow more immediate communication like internships, joint supervision, secondments, collaborative research and the creation of joint ventures are the most suitable for transferring tacit knowledge, while less media-rich activities like shared facilities and licensing patents consist of the transfer of explicit knowledge (Alexander & Childe 2013).

Actors have different motivations for why they engage in KT activities. Siegel et al. (2003) distinguish in addition to enterprises between various actors within the university, such as academics and technology transfer specialists. The actors have partly conflicting motives and organizational cultures that influence their participation in KT. Dutrénit and Arza (2010) distinguish in the case of enterprises between firm's benefits related to short-term production activities and long-term innovation strategies. Furthermore, nation states have their competitive interests, which could lead to technology-nationalism (Ponds, 2009). Different motives lead to different channels being used as academic engagement is undertaken mainly for expanding the base of knowledge and enhancing the reputation and careers of academics, while commercialisation intends to exploit an academic invention with the objective of financial gain (Perkmann et al., 2013).

Activities and outcomes relate to steps in the process of forming university-industry cooperation, and the benefits that are obtained. The number of stages from the identification of partners to signing an agreement that the formation of collaboration undergoes has been found to depend on its degree of formality and complexity (Ankrah & Al-Tabbaa, 2015). KT can involve relying on an existing network of contacts or intentionally seeking new external sources of knowledge. Studies on trajectory and intentional networks have found that previous interactions contribute to the formation of strong trusting relationships for accessing knowledge, while newer connections tend to be weaker and more formalised (Sousa & Fontes 2014). The benefits that KT leads to can be economic, institutional or social (Ankrah and Al-Tabbaa, 2015). But not all outcomes are positive as collaboration can lead to exploitation, negative impacts on students and unethical behaviour (Bozeman et al., 2013).

Influencing factors are those that either facilitate or inhibit KT. Actors are organized in networks of nodes (individuals or organizations) connected through more or less structured relationships (Granovetter, 1973; Krackhardt, 1992). The distance between various actors has several dimensions – cognitive, organizational, social, institutional and geographical (Boschma, 2005). Too much proximity has been found to be harmful, as excessive cognitive proximity (similarity in technological knowledge) reduces the possibility for novelty and learning, so partners should be rather located at an optimal cognitive distance to retain both mutual understanding and novelty (Nooteboom et al., 2007). Petruzzelli (2008) has concluded that high geographic, organizational and technological closeness is characteristic of developing joint intellectual property, while joint research projects require a more distant knowledge base.

While similarities in the content, channels and actors involved in the KT process can be found between international KT and KT in general, the differences in the institutional contexts the actors originate from add a unique dimension to U-I IKT studies. For example, Malik (2013), drawing on the analysis of international collaborations of 256 biotechnology companies found that whilst distance in terms of level of industrial development appear to negatively affect the transfer of university-generated knowledge across national boundaries, distance in religious, social, and educational institutions has a positive effect. IKT is also characterized by a lack of geographical proximity, in which case the absence of spatial proximity can be substituted by some forms of non-spatial proximity. In this vein, Hansen (2015) has found that

there is evidence of geographical proximity being replaced by cognitive, organizational and social proximity. Furthermore, temporary geographical proximity in the form of short visits can contribute to overcoming the problems created by distance (Knoben & Oerlemans, 2006), and the transfer of tacit knowledge between geographically distant partners.

In the current study, U-I IKT is understood as KT for either academic engagement or commercialisation purposes at the inter-organizational level mainly between individuals who originate from different types of organizations (universities and enterprises, and in some cases universities, enterprises and government) situated in different countries.

U-I IKT is seen as a two-dimensional concept. Firstly, it is characterized by specific channels, motivations, activities and outcomes, and influencing factors that form the building blocks of the university-industry collaboration process. These are partly similar to KT carried out within national boundaries, but there are also specific issues like national interests and technology protectionism, lack of geographical proximity, differing political, regulatory (incl. intellectual property protection), social and economic environments, and the importance of inter-governmental organizations like the EU and WTO. Secondly, U-I IKT has similar traits with other streams of research looking at the internationalisation of KT, namely the internationalisation of innovation systems, firm R&D activities and higher education institutions. U-I IKT is a wider field than these, as by definition it involves the interactions of different types of actors. At the same time, some internationalisation activities of higher education institutions may only involve university-to-university cooperation, firms participating in knowledge networks consisting only of other firms that are part of their supply chain, and government bodies cooperating with other government bodies across national borders.

2.2. Internationalisation of innovation systems

Carlsson (2006), in his comprehensive review of literature on Internationalisation of Innovation Systems (IIS) (national, regional, sectoral and technological), found only five studies dealing explicitly with the internationalisation aspects of innovation systems (Niosi and Bellon, 1994, 1996; Bartholomew, 1997; Fransman, 1999; Niosi et al., 2000). Niosi and Bellon (1996) showed that although national innovation systems are becoming more intertwined globally, the local and national networks are still important. Bartholomew (1997) studied the biotechnology sector in four developed countries (USA, UK, Germany and Japan) and found that 'tapping into foreign innovation systems through international cooperative alliances gives firms access to a wider range of solutions to technological problems' (p. 262). Fransman (1999) studied the degree of the internationalisation of the Japanese innovation system and found that even though Japan still lags behind other countries in terms of the internationalisation of its science and technology system, the degree of internationalisation has increased significantly over the last decades.

All these studies have indicated the increasing interdependence of innovation systems in different countries. At the same time, some scholars have noted the emergence of techno-globalism and argued that the role of the regional and national system of innovation could become less influential (Ohmae, 1990; Reich, 1991) and more internationalised. However, the later studies have shown that national policies and institutions still play a crucial role. Such studies can be said to address techno-regionalism/nationalism, and analyze how regional or national innovation systems facilitate the firms' activities and how different organizations

jointly create, diffuse and use knowledge in the region and nation (Lundvall, 1992; Nelson, 1993). However, there is no consensus among scholars on whether internationalisation has undermined the national /regional innovation systems or has strengthened them.

Therefore, the IIS focuses on ensuring the competitiveness of a country through cooperation and competition with other actors. While the central actor is government, enterprises and universities also play an important role here as part of the overall network.

2.3. Internationalisation of firm R&D

IKT between firms and its impact on the innovation performance of firms has been extensively studied (Marcon, 2012; Easterby-Smith et al., 2008). Most of these studies on Internationalisation of R&D (IR&D) are concerned with intra- or inter-firm transfer of knowledge across national boundaries, the co-evolution of a firm's knowledge base and external foreign sources of knowledge (Chuang, 2014). Scholars have also focused their analysis on how cultural, language/ institutional congruence between the headquarters and subsidiaries facilitates the smooth operations of the firm and the implementation of human resource management practices (Choi and Johanson, 2012; Simona and Axele, 2012; Welch and Welch, 2008). Some scholars have shown that collaboration with foreign firms contributes to the knowledge base of local firms and enhances their performance. In recent years, a few scholars have also focused their attention on the role of ICT in U-I IKT (Wu and Lee, 2012) and have argued that information technology can improve the quality and quantity of information exchange and have a positive influence on cross-border transfer of knowledge. However, IKT has been found to have some positive effects only in the case of a 'low context communication culture' and there is very little impact on KT in a 'high context communication culture' and on vertical and lateral linkages among different organizations (ibid.).

The general assumption of these studies is that KT between organizations takes place without a loss, which seems a faulty assumption. To overcome these problems, the concept of 'knowledge translation' has been developed, which takes into account the modification of knowledge when transferring from an MNE's headquarters (host country) to its foreign subsidiaries (Choi and Johanson, 2012). There are, furthermore, studies that have emphasized the limitations of applying a standardized and universal set of KT mechanisms without considering the local idiosyncrasies and the importance of local agents and institutions throughout the process of local knowledge adaptation (Hong and Nguyen, 2009). There is an emerging consensus that internationalisation raises a firm's tendency to innovate in terms of product development, R&D spending and patenting (Boermans and Roelfsema, 2015).

IR&D is concerned mostly with achieving global competitiveness on new markets for firms through competition. The central actors are MNCs or enterprises that establish partnerships with other enterprises, but also public research organizations in the host country diversifying their resources.

2.4. Internationalisation of higher education

Most of the studies dealing with the internationalisation of HEIs have generally focused on academic exchange, collaborative research networks, co-authorship and transnational career paths (Wong et al., 2007; Garrett-Jones and Turpin, 2012). Some scholars have also noted that the basic motive of universities approaching foreign firms is to gain/mobilise research funds.

For instance, Howells (1990) noted the increase in industry-university linkages on a transnational basis during the 1980s and highlighted the increasing involvement of Japanese companies with US higher education institutions. The internationalisation of university research systems was also noticed in the UK where research grants and contract income received by higher educational institutions from overseas, also including foreign firms, increased by 11.7% between 1995–96 and 1996–1997 (Howells and Nedeva, 2003).

This phenomenon has been called 'transnational academic capitalism', which refers to the integration of the transnational dimension in teaching, research and services in a way that enhances transnational integration between universities and globalising knowledge capitalism, and increases the opportunities for academics and universities to diversify their external funding sources transnationally (Kauppinen, 2012). In this way, higher education is integrating with transnationally mobile capital, and especially with those transnational corporations that are heavily involved in knowledge-intensive transnational economic practices. This has also led to the emergence of a specific route of internationalisation, which MNCs called 'collaborative doctoral education in university-industry partnership' (Borrell-Damian et al., 2010).

Some studies have, however, pointed out that an over emphasis on international collaboration in academia (e.g. joint academic publications) has not only weakened the domestic/national university-industry interactions but has also weakened the status of universities in the national innovation system (Howells, 1990). Therefore, the Internationalisation of Higher Education (IHE) is seen, on the one hand, as something positive and important, as almost all higher education institutions refer to their international dimension in mission statements and in the formulation of their profiles. On the other hand, internationalisation is considered a reflection of the existing international inequality between nations and world regions because about three-quarters of the world's mobility is vertical (Kehm and Teichler, 2007).

IHE relates mostly to enhancing the quality of education and mobilising the resources of HEIs. The central actors are universities and research organisations that establish partnerships with other universities, but also enterprises and government actors in foreign countries.

In conclusion, the internationalisation of the activities of countries, enterprises and universities has been studied under different streams such as internationalisation of R&D (IR&D) (Easterby-Smith et al., 2008; Marcon, 2012; Krishna et al., 2012), internationalisation of innovation systems (IIS) (Carlsson, 2006) and internationalisation of higher education (IHE) (Warwick, 2014; Kosmützky and Putty, 2015). These studies deal with the transfer of knowledge across national boundaries and underline motivating and inhibiting factors, different channels of KT and the outcomes of KT. The issues related to the transfer of knowledge overlap in the case of the different streams of literature, but they also possess their own motives and perspectives. While sharing the trans-boundary aspects of KT, IIS focuses on the cross-border activities of innovation systems facilitated by governments, IR&D looks at the internationalisation of firms and IHE centres on universities. U-I IKT can be seen both as an overlapping and separate stream of literature with elements similar to other areas of the internationalisation of KT as well as having its own specific features.

3. Methodology

In order to conduct a systematic literature review, the principles outlined by Tranfield et al. (2003) were followed in order to synthesize the studies on IKT between universities and industry. A systematic literature review was undertaken to facilitate answering a clearly formulated question by finding, describing and evaluating evidence from all published studies on topic(s) related to that question within a specific set of boundaries (Eriksson, 2013). A systematic review is different from the traditional literature review in which there is often no attempt to seek a generalisation or cumulative knowledge of what is reviewed, and such reviews are considered opportunistic, selective, haphazard, lacking a systematic and exhaustive search of all the relevant literature (Davies, 2000).

The objective of the current study was to establish what is known about the U-I IKT, particularly in the context of university-industry linkages. This objective was influenced by the observation that there is a considerable amount of literature on the issues related to the cross-border transfer of knowledge, but these studies are scattered under different themes such as IR&D, IIS and IHE focusing on the specific perspective of firms, government and higher education institutions, respectively. Therefore, a systematic review of the literature was deemed necessary to assess the current knowledge and collate the scattered findings and present them in a way that may provide collective insights and guidance in meeting the needs of policy makers, academics and managers involved in the cross-border transfer of knowledge.

Guided by these objectives, the following procedure was applied. First, all relevant studies published on this topic from 1970 to 2015 were identified using a variety of keywords and their combinations that related to U-I IKT and university-industry collaboration. The search was confined to two databases: Scopus and Web of Science, as these datasets abstract and index peer reviewed high-quality research. The keyword search covering of the terms "university industry", "international", "collaboration" and their synonyms1 produced a total of 423 articles (241 articles from Scopus and 182 from Web of Science). Only research articles published in the English language were included in the study. After deleting duplicates, we were left with 208 articles. Subsequently, the title, abstract and if necessary the whole text was carefully read, and in the end 82 articles remained. Both authors read the text of each article using the following criteria for deciding whether to include it in the study:

- Does the study address the issues of KT between universities and enterprises (and sometimes government) that are located in different countries?
- Does the study address research related activities of university-generated knowledge (rather than educational activities)?
- Does the study address U-I IKT as a central issue?

By applying these criteria, we were able to identify 22 studies that addressed IKT between universities and industry. We further used the snowballing technique and looked through the references of the selected articles to find other relevant studies. This rendered the final article

[1] The following keyword combinations were used in the literature search: "international" OR "transnational" OR "cross border" OR "cross national" AND "knowledge transfer"; "international university industry collaboration"; "university industry" AND "international collaboration" OR "international relations" OR "international linkages" OR "international cooperation" OR "international research" OR "international technology transfer" OR "international" OR "proximity".

count of 26 articles, which we read and synthesized by compiling the following information for each study in a tabular form: author and publication year, research questions, source of data, methodology, variables used and findings.

The articles that were selected for the analyses have been published between 2001 and 2015. The main outlets of these studies are: Journal of Technology Transfer (3 instances), Research Policy (3 instances), Scientometrics (2 instances) and Papers in Regional Science (2 instances). Only one article was published in each of the following journals: Economics of Innovation and New Technology, Environment and Planning A, European Journal of Innovation Management, FEP Economics and Management, Globalization, Societies and Education, EEE Transactions on Engineering Management, Information and Management, International Journal of Technology Management, Journal of Business and Industrial Marketing, Journal of Knowledge-based Innovation in China, Journal of the American Society for Information Science and Technology, Journal of the Association for Information Science and Technology, Journal of the Korea Academia-Industrial Cooperation Society, Research Evaluation, and Annals of Regional Science.

However, the paper is not without limitations. The paper addresses KT for either academic engagement or commercialisation purposes at inter-organizational level mainly between individuals who originate from different types of organizations (universities and enterprises, and in some cases universities, enterprises and government), which are situated in different countries. This means the study comprises partly organizational and partly individual level analysis, as individuals that cooperate do so in their organizational contexts. The study largely leaves aside research partnerships purely at the organizational level (e.g. Hagedoorn et al., 2000) and person-to-person interactions inside research groups (e.g. Hautala, 2011). This also means that the study looks at collaborations between different types of organizations, and does not cover university-to-university, firm-to-firm or government-to-government KT across national borders. In addition, the meta-analysis of previous research is confined to English language articles in two databases (Scopus, Web of Science), which covers only a part of the research published on the topic, as it excludes other languages and other types of publications. This was a necessary limitation in order to render the number of studies found using the keyword search manageable.

4. Results

4.1. Channels, motivations, activities and outcomes, and influencing factors of international knowledge transfer

4.1.1. Channels of international knowledge transfer

Certain channels or methods of cooperation are more suitable for either explicit or tacit knowledge to be transferred. In the case of the international transfer of knowledge, it has been observed that interactions with non-local universities generally include the transfer of codified forms of knowledge, while links with local universities include more tacit forms of knowledge (de Fuentes and Dutrénit, 2014) as it is difficult to transfer tacit knowledge without regular face-to-face contact. Breschi and Lissoni (2001) argue (drawing on Mansfield (1995)) that when local universities are not able to produce the basic research needed by enterprises, they turn to top universities, leaving local collaboration more for buying applied R&D services accompanied

also by more frequent face-to-face interaction. International activities have also been observed in co-incubation in which case start-up businesses are assisted to enter other national markets or benefit from specialised services when scientific, technological and commercial knowledge is absent in the home country but present in a partner country (Cooke et al., 2006).

Therefore, in addition to the explicit and tacit nature of knowledge, proximity is also important in terms of the division between 'basic research' and more 'applied R&D' services and market-oriented activities. In that vein, universities tend to favour larger and longer-term collaborative research projects because of the more basic nature of the research (Caloghirou et al., 2001). Close geographical proximity has been found to contribute to learning, trust, close and continuous interaction in short-term applied projects; while in the case of long-term projects, it is easier to work across geographical distances (Broström, 2010). Along similar lines, firms seeking business advice are more likely to collaborate with regional universities while firms seeking R&D support and testing and analysis services are more likely to collaborate with both regional and non-regional universities (Maria et al., 2014). At the same time, foreign investors are likely to choose local universities over local firms when the alliance has been established primarily for research rather than development purposes (Li, 2010).

4.1.2. Motivations for engaging in international knowledge transfer

In terms of research organizations, in addition to the local and regional role, universities also function at the international level and have to consolidate these different functions (Fromhold-Eisebith and Werker, 2013; Howells and Nedeva, 2003). It has been found that the quality of academic research and geographical distance are related in that higher performance research groups are more interested in cooperating with distant firms (Garcia et al., 2014), as international collaborations have higher citation impact than national and regional collaborations (Frenken et al., 2010).

Enterprises, on the other hand, are mainly interested in the financial gain, and secondly, in maintaining control over their technologies (Siegel et al., 2003). In terms of international collaboration, studies have shown that firms with higher levels of absorptive capacity tend to form more geographically distant links with universities (de Fuentes and Dutrénit, 2014), valuing, at the same time, the research quality of the university partner more than its geographical proximity (Laursen et al., 2011). Under the conditions of transnational academic capitalism, MNCs play an important role in interacting globally with universities (Kauppinen, 2012), and a number of studies have focused on alliances between MNCs and universities (Belderbos et al., 2014; Sorensen and Hu, 2014; Li, 2010). Studies have noted that MNCs resort to collaborating with local universities to take advantage of the host country's scientific and technological inputs, expand their capabilities, obtain complementary technologies or skills, achieve economies of scale in R&D, and better monitor the behaviour of their local and international competitors (Gassmann and Han, 2004), and to avoid the loss of information to competitors (Caloghirou et al., 2001). The SMEs, on the other hand, have been found to collaborate internationally more often as part of their supplier-customer relationships rather than with R&D organizations, which highlights the importance of organizationally close collaborates (de Zubielqui et al., 2015).

Different countries have different interests for IKT. In some 'R&D markets' like the USA and Japan, which are vast and highly developed in terms of local science-dependent industry, it is possible for a large proportion of university-industry interactions to take place domestically (Tijssen et al., 2009). Unlike most English-speaking and South-Asian countries that have

focused on increasing their share of the international market of higher education teaching services, France seems much more interested in developing a competitive R&D in the university-industry sector (Vinokur, 2010). It has also been found that in more economically developed English-speaking countries, the university sector plays a key role in international university-industry-government collaborations; while, in less-wealthy non-English-speaking countries it is the government that has this key role (Choi et al., 2015).

4.1.3. Activities in and outcomes of international knowledge transfer

There are several processes specific only to transferring university knowledge to industries across national boundaries. Jin et al. (2011) have distinguished between direct and indirect processes of U-I IKT between university and industry. Direct cooperation occurs between domestic universities and foreign companies, or between domestic companies and foreign universities. Indirect KT involves the local branches of MNCs as intermediaries between a domestic university and a foreign enterprise (headquarters of an MNC) or university. In addition, it is possible that indirect cooperation is also mediated by universities not only by enterprises. This would mean that it is the universities in different countries that primarily interact with each other and involve also local enterprises in this kind of cooperation.

Another perspective is embodied in studies that use the concept of a triple helix. Therefore, Sorensen and Hu (2014) have shown through a process view how the triple helix becomes internationalised through merging with the respective structure in another country. It was found that this process occurs in several stages: pioneering, exploration, and integration. In the pioneering stage, the authors see the establishment of each of the three spheres of the helix abroad – the internationalisation of companies, universities and governments; in the exploration stage, the three spheres start to interact abroad and collaborate with their counterparts in the host country; in the integration stage, helix-to-helix collaboration emerges.

The outcomes from engaging in international university-industry relations are complicated to assess. Several studies have compared the university-industry-government co-authorship relations nationally and internationally. Leydesdorff and Sun (2009) have found that the Canadian publication system is more internationalised than the Japanese, but national triple helix relations are much stronger in the Japanese system, as the former is better integrated with the Anglo-Saxon system. Kwon et al. (2012) have observed in the case of South Korea that the triple helix has eroded at the national level with increased internationalisation (as was previously found in Japan), but strengthening the national system is vital because of regional disparities in the ability to cooperate internationally. In Saudi Arabia, it was found that the triple helix collaboration does not differ between domestic and international collaborations, although there has been a rapid increase in international collaborations (Shin et al., 2012).

Bringing together the domestic and international level may prove problematic as international university-industry KT has been found to have negative outcomes. There are fears of domestically funded academic research leaking to foreign firms leading to techno-nationalism in research policy (Ponds, 2009). In addition, next to the caveats that more intensive university-industry collaboration is likely to decrease public control over university research and increase industry's influence resulting in more applied research, shorter research time and delays in publication, the internationalisation of research may leave the needs of smaller domestic firms (SMEs) inadequately addressed (Howells and Nedeva, 2003).

4.1.4. Influencing factors of international knowledge transfer

Geographical distance seems to foster more collaboration between similar types of organizations (e.g. between universities or between enterprises) because of institutional proximity, whereas collaboration between different kinds of organizations (e.g. university and industry) is more spatially confined (Ponds et al., 2007; Ponds, 2009). There are conflicting findings as to how geographical distance can be compensated. Although absorptive capacity has been found to increase cognitive proximity between partners, even if they are geographically distant (Jong and Freel, 2010), Araújo and Teixeira (2014) reported, based on 71 technological partnership agreements, that human capital and absorptive capacity are negatively associated with international technology transfer.

Different types of enterprises have varying abilities to overcome the difficulties created by the lack of geographic and other forms of proximity when cooperating internationally with universities. Geographic proximity has been found to be less important with the increase in the firm's R&D expenditure, activity in the North-American market and the importance of codified basic research results, while the quality and output of domestic public research organizations and the importance given to public science by the respondents increases the importance of proximity (Arundel and Geuna, 2004). Fransman (2008) has distinguished between large national and international R&D intensive firms, university spin-offs and SMEs concluding that the costs are highest for SMEs with little previous cooperation experience with universities. Similarly, Freel (2003) has found in the case of 597 manufacturing SMEs in the UK that the spatial distribution of firm linkages is positively affected by firm size, export propensity and the introduction of novel (radical) innovations. Belderbos et al. (2014) have also reported that MNCs with high capacity for R&D find a region lucrative based on its academic strength, including the supply of PhD graduates.

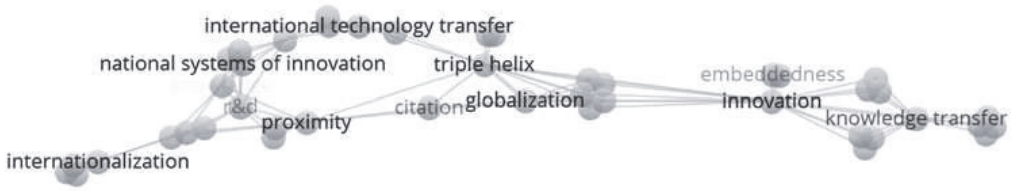
Existing studies emphasize the role of institutional proximity for the transfer of knowledge across national boundaries. Hwang (2010) discussed the interplay between organizational and national cultures and concluded that national barriers operate within an organizational system and long-term cooperation is needed to overcome those. Other studies have also confirmed that institutional differences affect KT across national boundaries, but different elements of institutions affect KT differently. For instance, Malik (2013) studied the interaction of 256 biotechnology firms from 24 countries and their sourcing of technology (measured in terms of licensing of patents) from universities located in 31 countries, and found that some elements of institutions (religious, social and educational distance) influence international technology transfer positively, while some elements (level of industrial development) influence it negatively, and yet some other elements of institutions (political distance) have no influence.

4.2. Connections between the internationalisation of knowledge transfer, innovation systems, higher education and R&D

U-I IKT is a wide area of activity that is a domain in its own right, and at the same time, also partly overlaps with other domains like the internationalisation of innovation systems, higher education institutions and enterprise R&D activities. In order to understand the inter-connections between different concepts used in U-I IKT studies, a bibliographic network of author keywords was produced with the help of the VOSviewer software. VOSviewer makes it possible to graphically represent bibliometric maps using among other means keywords from

articles based on co-occurrence data (van Eck and Waltman, 2010). Data from Web of Science and Scopus was used to construct a network of 69 author keywords from U-I IKT papers, and a graph representing bibliographic connections was produced that illustrates the entire network of concepts and their sub-groups. Analysis of the keywords from articles rendered four sub-groups of concepts (Figure 1). It was found that two sub-groups consist of firm R&D, national systems of innovation and university-industry-government cooperation, while another two cover higher education institutions and external linkages (SMEs, incubators).

Figure 1. Map of author key words from U-I IKT studies



Source: Compiled by the authors

KT across national boundaries is partly related to other areas such as IIS, IR&D and IHE. Based on the different concepts found in U-I IKT studies, a framework depicting the objectives, nature of activities, dominant actors, theoretical framework and policy implications of U-I IKT studies was developed, including the characteristics of U-I IKT and also similarities and differences with IIS, IR&D and IHE (Table 1).

Table 1. Linkages between the internationalisation of knowledge transfer, R&D, innovation systems and higher education

Parameters	Internationalisation of knowledge transfer (U-I IKT)	Internationalisation of R&D (IR&D)	Internationalisation of innovation systems (IIS)	Internationalisation of Higher Education (IHE)
Objectives	To strengthen national research system, contribute to innovation in firms, address the global problems related to environment, health and economy. Universalism-nationalism	To achieve global competitiveness, access new markets. Techno-globalism	To ensure the competitiveness of a country. Techno-nationalism	To enhance the quality of education, mobilise resources, advance in global rankings. Universalism-nationalism
Nature of activities	Cooperation and competition	Competition	Cooperation and competition	Cooperation and competition
Dominant actors	Integrated perspectives of universities, enterprises, governments and intermediary organizations	MNCs/enterprises	Government	Universities
Theoretical framework	Movement from 'mode 1'of knowledge production to 'mode 2'; social network theory; triple helix; dimensions of proximity; institutional theory; human capital theory	Resource based view, principal–agent theory, octopus model, international business theory, innovation theories	Social network theory, triple helix	Triple helix,human capital theory
Policy implications	Inclusive at international level: academics, enterprises, government	Inclusive at managerial level	Inclusive at government / international level	Inclusive at university as well as government level

Source: Compiled by the authors

It follows that U-I IKT consists partly of the elements of IIS, IR&D and IHE as the central actors in the studies are either universities, enterprises or government that interact for KT purposes. There are studies that address the issue of KT more from the standpoint is a full word of universities (Howells and Nedeva, 2003; Hwang, 2010), those that analyze cooperation patterns of enterprises, both MNCs and SMEs, based on enterprise surveys (Arundel and Geuna, 2004; Broström, 2010; Fransman, 2008; Freel, 2003; de Zubielqui et al., 2015), and those that address the entire national innovation systems including the various actors that are part of it (Jin et al., 2011; Sorensen and Hu, 2014).

At the same time, U-I IKT is a domain in its own right. There are studies that do not employ a specific actor-related viewpoint and look at bilateral or trilateral relations between university-industry or university-industry-government. This is undertaken for example in the context of EU cooperation projects and networks (Caloghirou et al., 2001; Cooke et al., 2006; Araújo and Teixeira, 2013), co-publication analysis (Tijssen et al., 2009; Choi et al., 2015; Frenken et al., 2010; Kwon et al., 2012; Leydesdorff and Sun, 2009; Ponds, 2009; Ponds et al., 2007) and co-patenting analysis (Shin et al., 2012; Malik, 2013). These studies fall more under the stream of U-I IKT having features that are unique compared to other streams of literature.

5. Discussion and conclusions

The paper aimed to construct a framework for understanding university-industry international knowledge transfer. This was achieved by synthesizing existing literature in order to answer the following research questions: *(i) Are there specific channels, motivations, activities and outcomes, and influencing factors characterizing university-industry international knowledge transfer, and (ii) How is the concept of university-industry international knowledge transfer related to the internationalisation of R&D, internationalisation of innovation systems and internationalisation of higher education.*

It was found that international KT shares many similarities with KT in general, but there are also additional complexities that collaborative activities across boundaries need to address. The channels suitable for U-I IKT depend on the content of university-industry cooperation, namely the nature of the knowledge to be transferred. Geographical distance has been found to be less disruptive for the transfer of explicit and basic research related knowledge, as it is difficult to transfer tacit knowledge over long distances and the more applied needs of enterprises can be addressed by local universities. Therefore, when a firm does not get the required quality of basic research at home, it collaborates with universities located in other countries particularly in the case of long-term R&D projects (Broström, 2010).

The basic motives for undertaking cross-border collaboration are that such co-publications (also with industry) tend to receive more citations than collaboration at national or regional level (Frenken et al., 2010). However, mainly large firms with export potential are involved in U-I IKT, while small firms involved in incremental innovations are more locally embedded (with the exception of R&D intensive small firms like academic spin-offs). In terms of geographical differences, peripheral universities, particularly in the European context are participating more in international university-industry joint ventures (Caloghirou et al., 2001); whereas, other universities in Europe and Asia-Oceania are collaborating more frequently with American countries than in their own regions (Choi et al., 2015).

The processes of U-I IKT in terms of how cooperation progresses through different stages have been addressed little by previous studies. Nevertheless, Sorensen and Hu (2014) have

documented the internationalisation process of an entire triple helix (university-industry-government), which advances from the establishment of each of the spheres abroad to actual helix-to-helix cooperation. The negative outcomes of U-I IKT are addressed in studies, as there are fears of domestically funded academic research leaking to foreign firms (Ponds, 2009) and more intensive international collaboration resulting in more applied research, shorter research time, delays in publications, and treating the needs of smaller domestic firms as secondary (Howells and Nedeva, 2003).

The studies dealing with the cross-border transfer of knowledge have shown that relationships, cultural awareness and common language are the key factors affecting the transfer of knowledge (Duan and Coakes, 2010). While higher absorptive capacity has been shown to contribute to increased cognitive proximity between the network partners, there are also findings that refute this (Araújo and Teixeira, 2013). Still, the probability of R&D projects being located in a host region is positively affected by the host region's academic strength even (Belderbos et al., 2014).

In addition to the characteristics of U-I IKT, the literature review also indicated that U-I IKT has common themes with studies in areas like IIS, IR&D and IHE, as all these streams of research address the issue of the transfer of knowledge, albeit from a different perspective. Although under each theme, there is a growing diversity of issues, like techno-national vs. techno-globalism and cooperation vs. competition, the topic of cross-border knowledge transfer echoes in all of them. However, there are also differences, as U-I IKT is different from IR&D, IIS and IHE in terms of objective and nature, actors, theoretical framework and policy implications. U-I IKT is unique from other areas of study in that it embodies a multi-actor view addressing the issue of KT from bilateral or trilateral university-industry or university-industry-government perspectives.

The paper contributes to the existing body of knowledge by proposing a framework of U-I IKT consisting of the characteristics of the KT process and its connections to other research streams in the area of the internationalisation of KT. Firstly, as with KT that takes place within national boundaries, IKT can also be understood as a process consisting of channels, motivations, activities and outcomes and influencing factors. U-I IKT is influenced by institutional differences between countries and by a lack of geographical proximity between the actors. A lack of geographical proximity in U-I IKT can be compensated through various ways like temporary geographical proximity and higher levels of absorptive capacity, but it requires an assessment of costs and benefits and a compromise in terms of the quality of knowledge and cost of cooperation. Secondly, U-I IKT is partly connected to other streams of research dealing with the issues of the internationalisation of KT. Although keywords related to IIS, IR&D and IHE were not used when searching for the articles, these concepts are present in U-I IKT studies. Therefore, the phenomenon of KT from universities to industries across national boundaries can be explored under four main themes – IKT, IIS, IR&D and IHE. Most of the studies on IR&D, IIS and IHE have analyzed KT from the perspective of enterprises, government and university respectively, whereas U-I IKT can be seen as a convergence of the perspective of government, university and industry overlapping with the boundaries of other streams of literature. As U-I IKT is concerned with cooperation between different types of actors from different institutional contexts over long distances, it increases the complexity of these networks. One way to manage this complexity is offered, for example, through EU research programmes and other inter-governmental organizations that provide a legal and financial framework for such cooperation.

In terms of analyzing U-I IKT studies, this type of meta-analysis needs to be repeated over the course of time, as at present only 26 studies were found that met the research criteria. A larger number of studies would allow for a more in-depth analysis of the elements of the U-I IKT process. It would be especially interesting to pursue studies that document the stages of activities undertaken in such a process. This would also make it possible to compare the channels, motivations, activities and outcomes, and influencing factors of IKT more systematically to the characteristics of KT within national boundaries. In addition, a further area of research consists of studying the institutional differences in international cooperation. This involves formal and informal institutions at country, organizational and individual level. Locating the most critical factors that should be present can prevent international collaborations from ending up in failure. Lastly, when university research systems are being internationalised, the apprehensions related to leaking domestically funded research and the marginalisation of local SMEs need to be addressed in future studies. The practices are different as some countries have policies in place that favour the commercialisation of intellectual property from universities to domestic firms, while others encourage commercialisation in general, including at the international level. It follows that there are different measures in place to deal with the negative consequences of the international transfer of knowledge, and these need further attention.

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List of selected other publications

Kalantaridis, C.; Küttim, M. (2020). University Ownership and Information about the Entrepreneurial Opportunity in Commercialisation: A Systematic Review and Realist Synthesis of the Literature. The Journal of Technology Transfer. 10.1007/s10961-019-09757-6.

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Valik teisi publikatsioone

Kalantaridis, C.; Küttim, M. (2020). University Ownership and Information about the Entrepreneurial Opportunity in Commercialisation: A Systematic Review and Realist Synthesis of the Literature. The Journal of Technology Transfer. 10.1007/s10961-019-09757-6.

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