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Knowledge transfer and networks: collaboration as a key driver for innovation systems

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KNOWLEDGE TRANSFER AND NETWORKS: COLLABORATION AS A KEY DRIVER FOR INNOVATION SYSTEMS

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DOCTORAL THESIS

Knowledge Transfer and Networks: Collaboration as a Key Driver for Innovation Systems

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Facultad de Economía y Empresa
2022

A mis tres fantásticos

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Zaragoza, a 24 de agosto del 2022

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Chapter 1

Introduction

Introduction

1. Motivation

Traditional innovation strategies regard R&D investments as a cornerstone of innovation systems. As individuals face increasingly complex institutional and industry environments (Teigland & Wasko, 2009), this approach is no longer successful (Chen et al., 2019; Hervás-Oliver et al., 2021). Innovation success is contingent on the interaction in which entities engage, for it is difficult to imagine them operating in an isolated manner.

The European Commission[1] points to the need to create collaborative innovation ecosystems that strengthen the relations between member states, allowing the generation of economic growth and innovation. Proof of this interest are the Horizon 2020 strategies and the consequent Horizon Europe, which seek to strengthen the established relationships between companies and countries and at the same time promote new possibilities for collaboration. All this, has the final goal of increasing the innovative capacity of the European territory and, therefore, contributing to economic development and social welfare.

This change in innovation systems stems from the need to access resources outside the boundaries of the system. In this sense, previous literature seems to indicate that external resources can become generators of sustainable competitive advantages (Easterby-Smith et al., 2008; Szulanski, 1996) and therefore be key to achieving successful innovations in these innovation systems (Boschma & Ter Wal, 2007). However, how can access to external resources that provide value be achieved? This

[1] For further information: https://ec.europa.eu/research-and-innovation/en/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/building-european-innovation-ecosystem

doctoral thesis defends the idea that being part of a collaborative network is one of the fundamental mechanisms for accessing valuable external resources.

Given that, in recent years, the need for knowledge sharing among external agents has become evident, this dissertation is situated in the paradigm of the knowledge-based economy (Powell et al., 2004). This paradigm uses information as a fundamental element to generate value through its transformation into knowledge.

The process of knowledge exchange between agents has been referred to in the academic literature as knowledge transfer (KT). Specifically, this doctoral thesis makes use of the definition proposed by Argote and Ingram (2000) who refer to KT as *"the process through which actors exchange, receive and are influenced by the experience and knowledge of others"*. Note that, in the literature, there is some confusion when using the terms *knowledge sharing* and *knowledge transfer* (Tangaraja et al., 2016). In this document, it is considered that there is a certain difference between the concepts, understanding that *knowledge transfer* refers to a bidirectional and macro-level process and *knowledge sharing* to a unidirectional and micro-level process.

To achieve access to valuable knowledge and KT processes, the creation and use of collaborative relationships is vital (Hemmert, 2019; Tallman & Chacar, 2011). In other words, collaborative networks are a concept strongly linked to KT. The underlying rationale is that, through collaboration, firms gain access to external knowledge that they would otherwise not be able to access. Therefore, the network element seems to be important for the creation of new knowledge and its transfer, as networks act as facilitators, channelling knowledge flows (Boschma & Ter Wal, 2007; Gertler & Levitte, 2005; Owen-Smith & Powell, 2004).

Although the study of KT has generated debate in academia during the last decades, the fact that it is a young discipline has provoked different approaches to the research questions, generating some academic disorder. This, added to the fact that public and private institutions recognise the importance of transferring knowledge, makes it necessary to deepen the understanding of the complexity of these processes from a network perspective. In this sense, this doctoral thesis addresses the interest detected in understanding how knowledge flows are articulated in collaborative networks and how these impact on innovation capacity. The main objective is to contribute to the literature on KT and collaborative networks from three different perspectives: theoretical, exploratory and empirical.

The following sections attempt to contextualise and frame the thesis theoretically, exploratorily and empirically. Section 2 explains the academic theories by which this thesis is circumscribed. Section 3 identifies the research gaps identified and the objectives of the thesis. Section 4 describes the empirical context of the research. Finally, Section 5 describes the structure, content and contributions of the dissertation.

2. Theoretical framework

This doctoral thesis attempts to integrate three theoretical research streams (see Figure 1). The main foundations of each of them, as well as their relevance to this research, are explained below.

Knowledge-based view

In the current era, and within an economic and business context characterised by phenomena such as globalisation, high competitiveness, digitalisation and the dynamic nature of new markets, knowledge represents one of the most critical values to achieve sustainable success (Grant, 1996; Kogut & Zander, 1992; Nonaka, 1991). This paradigm is recognised as the "knowledge economy" where information, intelligence and experience constitute the basis of organisations. Thus, the ability to acquire information, transform it into knowledge, learn it, share it quickly and put it into practice constitute the most important organisational capacity to face the turbulence of the environment (Grant, 1996; Nonaka, 1994).

In the early 1990s, several streams of research converged to produce what has come to be described as the knowledge-based view (KBV) of the firm. Among these, the resource-based view (RBV) has been particularly influential. The KBV, proposed by Grant (1996) in his seminal paper *"Towards a knowledge-based theory of the firm"*, identifies knowledge as one of the firm's most important resources whose strategic properties have significant implications for the creation and maintenance of competitive advantage (Inkpen & Tsang, 2016) and for the implementation of strategy through management structures and systems. Despite the interest in the study of KBV, it has not been considered a new theory of the firm but a theoretical stream that attempts to conceptualise the firm as an institution for the creation, storage, processing and application of knowledge.

Barney (1991), in his pioneering work on RBV, identified the importance of transferability of resources and capabilities. Grant (1996) specified it for knowledge. Both concluded that this transferability is a determining factor in conferring sustainable competitive advantage, inside and outside a firm (Kogut & Zander, 1992). This doctoral thesis studies KT processes, understanding KT as the most relevant intangible resource in a knowledge-based economy. This resource is especially important when seeking to develop innovations in a context full of complexities, such as the one described in previous sections. However, research that studies knowledge as a strategic resource encounters difficulties in its analysis, difficulties that are fundamentally related to problems in its definition and measurement.

In this thesis, each of the chapters tries to contribute to KBV by firstly considering knowledge as the most valuable resource in innovation systems and secondly by analysing KT processes in Europe considering the complexities of the context.

Network theory

Borgatti and Halgin (2011) point out the need to differentiate between what they call *"network theory"* per se and *"theory of the network"*. Network theory refers to the mechanisms and processes that interact with network structures to produce certain outcomes for individuals and groups. In the terminology of Brass (2012), this theory deals with the consequences of network variables, such as having many ties or being centrally located. In short, it studies the way in which the elements of a network interact. In contrast, the theory of the network is concerned with the processes that determine why networks have the structures they have, i.e., the antecedents of network properties.

The management literature, and more specifically, the business innovation literature, has identified the need to understand the structures of networks. In this way, it will be possible to identify weaknesses, strengths and lines of action that allow to increase innovation (Aalbers et al., 2013; Cabrera-Suarez et al., 2018). In this sense, Tsai (2001) revealed that the position in a network significantly affects innovation and business unit performance.

Consequently, to achieve a better understanding of KT, it is important to analyse the network structure (Breschi & Catalini, 2010; Ye et al., 2020). Innovation will be based, in part, on the accessibility to new and valuable knowledge that depends on the structure of the network, such as the location of agents (Mason & Leek, 2008) and the structure and composition of links (Ghosh & Rosenkopf, 2015).

Given its implications, KT across interorganisational networks has attracted academic attention. The literature points out that, depending on the organisational characteristics of the network (Owen-Smith & Powell, 2004), the creation of KT networks between organisations promotes externalities that in turn generate innovations (Baptista, 2001; Malsch & Guieu, 2019) and a real impact on regional competitiveness. In this doctoral thesis, through Chapters 3 and 4, we try to contribute to network theory by deepening the understanding of the consequences on innovation of occupying certain positions and roles in the knowledge network.

Innovation Systems framework

"Innovation Systems Approaches view innovation in a more systemic, interactive and evolutionary way, whereby new products and processes are brought into economic and social use through the activities of networks of organisations mediated by various institutions and policies" (Hall et al., 2004). At the core of the focus of this stream of literature is the emphasis on economic and social interactions between agents, spanning the public and private sectors to generate and diffuse innovation within regions embedded in broader national and global systems.

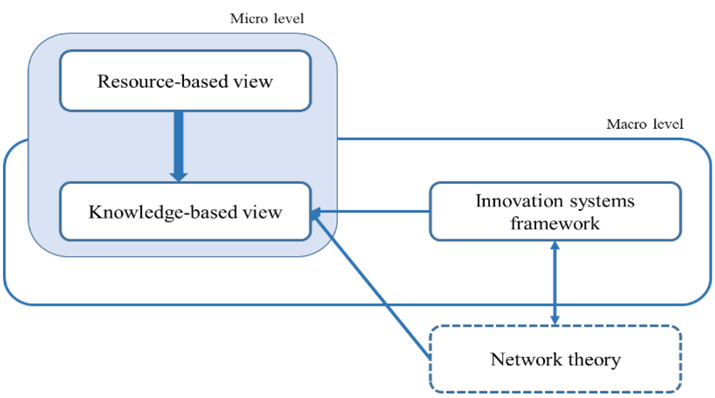
This stream of literature emerged in the 1980s when it began to be argued that differences in innovative performance are due to the industrial district in which firms are located. Subsequently, the concept of a national innovation system became relevant, arguing that innovative differences are not only due to industrial differences, but also to the existence of institutional characteristics and more complex structures that influence them. However, the theoretical level of disaggregation is still limited, since imbalances continue to exist within a country. There are regions that act as individual innovation systems which are in continuous interaction with each other.

The term "Regional Innovation System" (RIS) is attributed to Cooke (1992). It is theorised that in network-based RISs, firms are actively engaged in cooperative activities through joint investments and new forms of organization. These external collective economies, which are built through cooperation rather than market competition, are external to the firm but internal to the network and require the active rather than the passive participation of firms. Networks are therefore regionally and institutionally integrated and it is this richer set of relational linkages that is at the core of the RIS concept.

At the theoretical level, RIS research has modelled the innovation process in the context of a complex system. Knowledge is considered a central element of this system, and previous literature has identified the importance of the geographical dimensions of KT as a key variable determining regional innovation performance. The development of the RIS approach has begun to improve the understanding of the complexities of regional innovation. However, the field remains relatively new and its development has raised a number of unresolved research questions and new challenges for policy-makers.

This thesis, through its Chapter 4, seeks to contribute to this stream of literature by analysing how position, leadership and participation in a knowledge network are variables that influence a region's innovation capacity.

Figure 1. Theoretical framework



3. Research objectives

Considering the theoretical framework of this research and the research needs identified, the thesis reports on four studies, two theoretical, the third exploratory and the last empirical. Each study addresses different research objectives and focuses on answering unresolved questions to reach a better understanding of KT processes in collaborative networks.

The main research objectives are:

Research objective 1. *To develop a bibliometric study on KT and networks with the aim of reaching a better understanding of the discipline.*

Research objective 1.a. To recognise the most influential contributors in the field.

Research objective 1.b. To understand how the discipline has evolved.

Research objective 1.c. To identify the main emergent research areas and which are the main future avenues of the discipline.

Research objective 2. *To provide a comprehensive literature overview of KT and collaborative networks.*

Research objective 2.a. To discover the main conceptual findings of the studies focused on KT analysis and collaborative networks.

Research objective 2.b. To examine the antecedents, determinants and effects of KT on innovation and performance.

Research objective 2.c. To examine the role that those different contexts and institutions play in the processes of knowledge dissemination.

To address these two research objectives, we developed two theoretical studies (Chapter 2). The first one explores, through a bibliometric analysis, the evolution of the discipline, its origins and its present, identifying at the same time the major contributors to the literature. The second study focuses on the theoretical contributions of the last 20 years, systematising the most relevant findings for the discipline.

Research objective 3. *To enhance the understanding of the complex relationships that are developed in the European ecosystem.*

> *Research objective 3.a. To evaluate the research landscape in Europe that promotes innovation in SMEs through analysis of Horizon 2020 strategy funding.*

> *Research objective 3.b. To explore the position of each of the agents making up the Triple Helix model in their role as active subjects in research into innovation in SMEs.*

This research objective is addressed in Chapter 3. This study examines the European research ecosystem that drives innovation in SMEs. In addition, it examines the position of each agent in the knowledge network at the country, firm, and Triple Helix (TH) model level. Through this study, we aim to gain a better understanding of the functioning of the European research network for innovation.

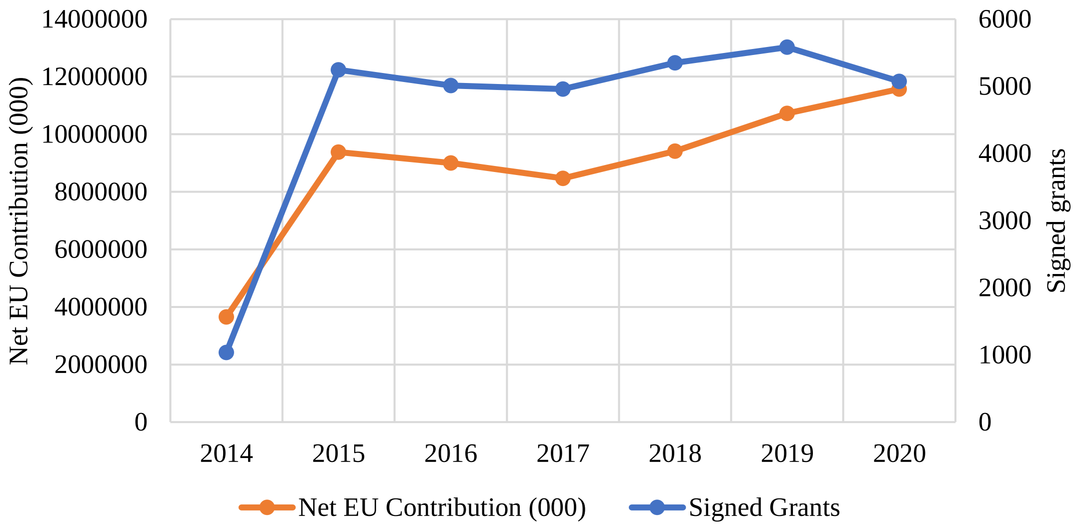
Research objective 4. *To investigate the influence of the structure of a knowledge network that relies primarily on collaboration on regional innovation capacity and the mediation effect of KT.*

To address this objective, we designed an empirical study (Chapter 4). Our research attempts to shed light on the question of whether having a particular network structure really influences the innovativeness of RISs. A two-step longitudinal and macro research using complex networks is proposed and then the hypotheses are econometrically tested. Empirical evidence is provided that contributes to the integration of the three theories presented in previous sections and fills the research gaps identified in the theoretical studies.

4. Empirical context

Chapters 3 and 4 of this doctoral thesis make use of data from the European Strategy Horizon 2020 (H2020). This strategy is defined as the strategy of European collaborative project strategies. H2020 was the EU's research and innovation funding programme from 2014 to 2020 (see the evolution of the funding in Figure 2 with a budget of nearly €80 billion. As described above, the study of collaborative innovation has been receiving increasing attention in the last years (Najafi-Tavani et al., 2018; Wang & Hu, 2020). In this sense, several empirical studies in recent years have made use of information from this strategy (Enger, 2018; Mulier & Samarin, 2021).

Figure 2. Evolution of the H2020 contribution and grants (2014-2020)



H2020 is divided into three pillars (see Table 1), Excellent Science, Industrial Leadership and Societal Challenges. The Excellent Science pillar of H2020 supports world-class science in Europe by developing, attracting and retaining research talent and supporting the development of the best research infrastructures. Industrial Leadership supports key technologies, aims to attract more private investment and support the growth of innovative SMEs in Europe. The Societal Challenges pillar supports research aimed at society and citizens. It supports the development of breakthrough solutions coming from multidisciplinary collaborations, including social sciences and humanities.

In this thesis, information on the second pillar of the H2020 strategy is used, since, given the objectives of this research, which focuses on a business innovation context, projects in this category are better suited than those in the other categories. Chapter 3 makes use of the category "Innovation in SMEs" within the second pillar of the strategy. Specifically, 1,055 research projects that promote innovation in SMEs are analysed in aggregate. In Chapter 4, data from the entire second pillar are used, allowing dynamic analysis of 8,424 projects from 232 European regions.

Table 1. Pillars of Horizon 2020

1. Excellent Science	**Million €**
European Research Council (ERC): Frontier research by the best individual teams	13,095
Future & emerging technologies: Collaborative research to open new fields of innovation	2,696
Marie Skłodowska-Curie actions (MSCA): Opportunities for training and career development	6,162
Research infrastructures (including e-infrastructure): Ensuring access to world-class facilities	2,488
2. Industrial Leadership	**Million €**
Leadership in enabling & industrial technologies (LEITs): (ICT, nanotechnologies, materials, biotechnology, manufacturing, space)	13,557
Access to risk finance: Leveraging private finance & venture capital	2,842
Innovation in SMEs: Fostering all forms of innovation in all types of SMEs	616
3. Societal Challenges	**Million €**
Health, demographic change & wellbeing	7,472
Food security, sustainable agriculture and forestry, marine/maritime/inland water research and the bioeconomy	3,851
Secure, clean & efficient energy	5,931
Smart, green & integrated transport	6,339
Climate action, environment, resource efficiency & raw materials	3,081
Inclusive, innovative & reflective societies	1,310
Secure societies	1,695

This strategy is particularly appropriate for this research for several reasons. First, it is the most ambitious strategy known in Europe to date, both economically and in terms of individuals involved. In this regard, Figure 3 shows the top 20 countries according to European funds obtained. In general terms, those countries correspond to those that are most involved in the initiative.

Figure 3. Distribution of the funding and participation across countries (Top 20)

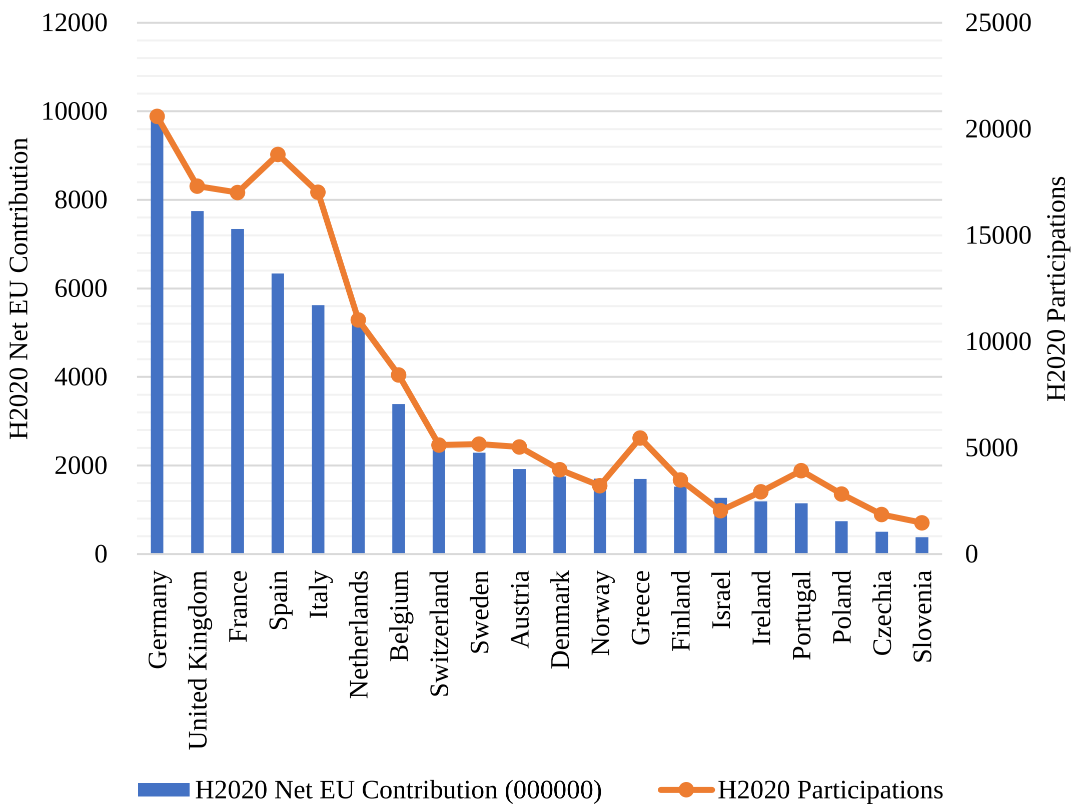


Table 2 shows the top ten organisations that have attracted the most funds. There is a conglomerate of organisations of different natures, such as research centres, universities or public institutions. These organisations are also the ones more participative (all of them exceed 500 participations). It is remarkable that the first and the second (in terms of contribution) are based in France, while the third and fourth are in Germany and the following two in the United Kingdom.

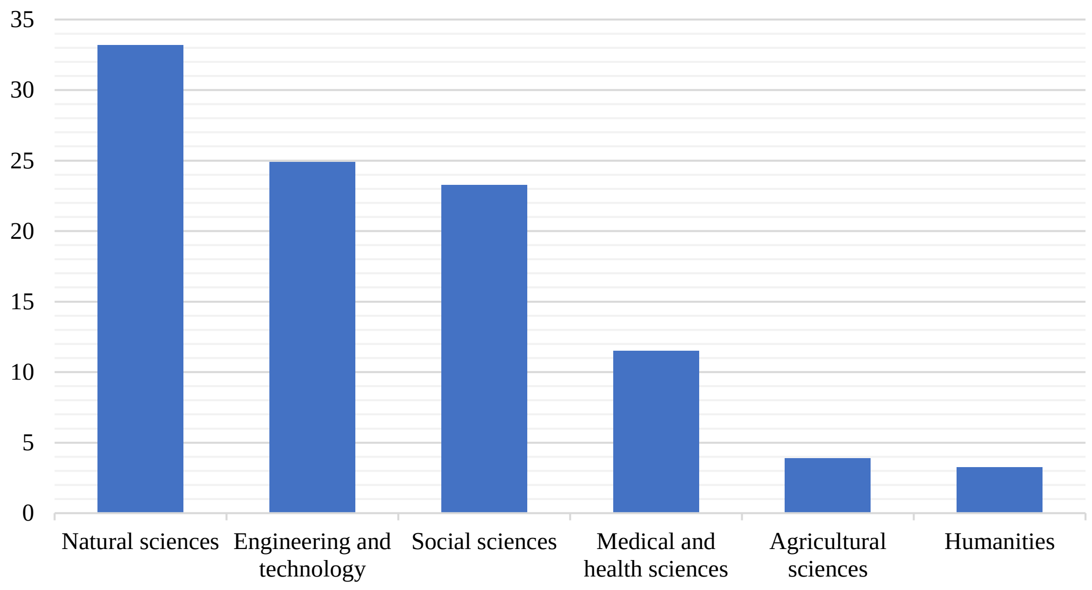
Table 2. Top 10 organisations by contribution in H2020 strategy

	Legal Name	Country	H2020 Net Contribution (000)	Participation
1	Centre National de la Recherche Scientifique CNRS	FR	€ 1,153,012.63	1,868
2	Commissariat A L Energie Atomique et Aux Energies Alternatives	FR	€ 689,964.77	779
3	Fraunhofer Gesellschaft Zur Foerderung der Angewandten Forschung E.V.	DE	€ 664,392.24	1,102
4	Max-Planck-Gesellschaft Zur Forderung der Wissenschaften Ev	DE	€ 649,590.74	662
5	University of Oxford	UK	€ 506,818.59	716
6	University of Cambridge	UK	€ 455,678.07	755
7	Eidgenoessische Technische Hochschule Zuerich	CH	€ 428,217.06	593
8	University College London	UK	€ 410,559.25	656
9	Agencia Estatal Consejo Superior de Investigaciones Científicas	ES	€ 373,404.97	882
10	Kobenhavns Universitet	DE	€ 368,990.85	692

Secondly, by its nature, this strategy finances research projects that seek innovations in different areas (see Figure 4) but which ultimately seek to improve the welfare of European society by fostering collaborative relationships. In short, it is a strategy that focuses on projects that seek innovation and are organised in the form of a consortium. That is, a project has a coordinating agent and executing agents or participants.

Figure 4 summarises the percentage of the contribution according to the thematic areas in which projects are categorised. The first two categories (natural science and engineering and technology) represent more than a half of the contribution. Also, projects that foster some kind of innovation in relation to social science are attracting attention.

Figure 4. H2020 contribution by thematic areas (%)



In this sense, and thirdly, given that this doctoral thesis adopts a network perspective, the H2020 information allows the creation of directional matrices, where KT is measurable from one point to another, i.e., from one agent to another. The strategy allows identifying different levels of analysis such as organizations, regions or countries among others, so knowledge flows can be measured between them.

Finally, and linked to the previous points, this strategy is international in scope, allowing researchers to analyse complex ecosystems that the management literature has identified as research gaps. This offers numerous policy and practical implications that will be detailed in the next sections, as well as in the content of the chapters themselves and in the conclusions of this doctoral thesis.

5. Thesis structure

This doctoral thesis seeks to deepen the understanding of knowledge exchange flows. In the following chapters, we focus on the study of KT through collaborative networks in an interorganisational and European context. Figure 5 shows an overview of the structure of the thesis, which is explained below.

The thesis is composed of five chapters. Chapter 1, *Introduction*, explains the main objective of the thesis as well as the contribution, thus situating it in the literature of knowledge management and business innovation. This introductory chapter also presents the theoretical framework by which the thesis is framed and the empirical context of the thesis, explaining the theories employed and justifying the choice of the Horizon 2020 strategy for the purpose of the research.

Chapter 2 is entitled *Theoretical foundations*. This chapter reviews the literature studying KT linked to the use of collaborative networks. We detect a lack of systematisation of the literature analysing this phenomenon. Although KT and collaborative networks constitute a research topic that has attracted the attention of researchers, it has been approached from very diverse perspectives, which has led to some theoretical disarray. This first block of the thesis is composed of two studies that make use of two different methodologies of literature analysis, bibliometrics and systematic review.

The first study is entitled *The evolution of knowledge transfer and networks literature stream: A bibliometric approach* and explores 774 research articles on the phenomenon, identifying the origin of the discipline, as well as current trends and potential future lines of research. The second study, entitled *Deepening the understanding of knowledge transfer and networks' foundations: Future research lines and challenges*, analyses the content of 190 high-impact articles to systematise the main academic findings and identify the most important current research gaps. The contribution of this chapter is twofold. First, we survey and order the academic literature of the last 20 years providing a clear conceptual framework for the origin, the findings explored and the future lines of research. Second, we detect a clear evolution in the approach from which the discipline has been studied. There is a call for works with a dynamic and macro perspective that focus on the context. This chapter allows us to identify the current point of interest within the study of KT as well as to identify the research gap for this thesis.

Chapter 3, *Exploring knowledge transfer ccosystems*, consists of an exploratory study, *The European research landscape under the Horizon 2020 Lenses*. This research explores the KT occurring in Europe using the Triple Helix theoretical model. In this work, the knowledge flows in a network of research projects on innovation in SMEs are visualised. Previous studies point out the importance of collaborative networks for this type of firms given the lack of infrastructure and resources to carry out innovations by themselves. In addition, the aim is to explore which are the driving agents of innovation in SMEs in the European context. For this purpose, methodologies based on the analysis of complex networks are used, and the general ecosystem is explored from a static perspective.

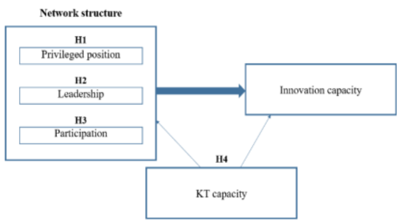
The main contribution of Chapter 3 is the visualisation of European knowledge flows for the achievement of innovation in SMEs. In particular, our results find that large scientific centres are the key drivers of SME innovation in collaborative networks. In addition, we examine the ecosystem from three perspectives that allow for a greater and better understanding of the knowledge network. This study contributes to the knowledge management literature by filling a research gap detected in previous chapters.

Chapter 4, *Do Collaboration structures matter in regional innovation systems?*, aims to go a step further and analyse empirically whether having certain structural features in a knowledge network matters for the innovation capacity of a regional system. Building our reasoning on the innovation systems literature, the resource-based view and network theory, we argue that having a privileged position, in terms of centrality, being a leader and being an active participant in a collaborative knowledge network, has a positive impact on the innovation capacity of a regional system. Furthermore, we propose that this relationship will be enhanced if, in addition, there is a high capacity for KT. This research makes use of longitudinal panel data and fills a research gap uncovered in the first theoretical block of the thesis.

The contribution of Chapter 4 is threefold. First, we contribute to the literature by integrating three theories, bringing together concepts such as KT, regional innovation systems and complex networks. Second, we answer the call for macro-level and dynamic empirical studies, offering empirical evidence on a database of 232 European regions and more than 8,000 collaborative projects in a 7-year panel data. Finally, we offer a two-step empirical study; first, we construct network structure variables making use of the network-based methodology, and subsequently, we test the model econometrically, providing support to previous literature.

Finally, Chapter 5, *Summary and Conclusions*, offers a general review of the arguments and results obtained in this doctoral thesis. In addition, Chapter 5 presents the academic and practical conclusions and implications derived from this dissertation that may be useful for researchers, policy-makers and managers.

Figure 5. Structure of the doctoral thesis

	STUDY	OBJECTIVE	METHOD	CONTRIBUTION
CHAPTER 2	Study 1. The evolution of knowledge transfer and networks literature stream	*RQ1. Who are the most influential contributors?* *RQ2. How has the discipline evolved?* *RQ3. What are the main emergent research areas?*	Three-step bibliometric analysis. 774 papers (2000-2020).	Hot research area in the last 20 years. Micro and static perspective → Macro and dynamic
	Study 2. Deepening the understanding of knowledge transfer and networks' foundations	*RQ1. What are the main conceptual findings?* *RQ2. What are the antecedents, determinants and effects of KT?* *RQ3. What role do different contexts and institutions play?* *RQ4. What are the main research gaps and trends?*	Systematic literature review 190 papers (2000-2020)	It offers a systemic view of the functioning of KT and collaborative networks. It improves the understanding of the determinants and consequences of the KT.
CHAPTER 3	Study 3. Exploring knowledge transfer ecosystems: The European research landscape under the Horizon 2020 Lenses	*(1) To evaluate the research landscape in Europe that promotes innovation in SMEs through analysis of Horizon 2020 strategy funding* *(2) To explore the position of each of the agents making up the Triple Helix model in their role as active subjects in research into innovation in SMEs.*	Network analysis 1,055 projects from Horizon 2020 (2014-2019) 1. Degree centrality. 2. Closeness centrality. 3. Betweenness centrality. 4. Eigenvector centrality.	There is no clear connection between the quantity received from H2020 and the strategic positioning in terms of connectivity. BSCs emerge as key drivers of innovation for SMEs. It contributes to the visualisation of the European ecosystem agents that fosters innovation in SMEs.
CHAPTER 4	Study 4. Do collaboration structures matter in regional innovation systems? Evidence from European knowledge transfer dynamics	*(1) To test the impact of network structure properties on regional innovation capacity* *(2) To understand the role of KT as a mediator by channelling knowledge flows* 	Panel of 232 European regions (2014-2020). Two-step analysis: 1. Network analysis. 2. Random effects Tobit regression. Additional analysis: 1. ANOVA.	*All direct hypotheses supported.* *Mediation partially supported.* It integrates three literature streams (KBV, innovation systems and network theory). It contributes to the understanding of the evolution of macro innovation policies. It shows the importance of collaboration across RIS. Policy implications.

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Chapter 2

Theoretical foundations

Study 1

The evolution of knowledge transfer and networks literature stream: A bibliometric approach

1. Introduction

Previous literature has evidenced the importance of knowledge as an intangible asset in a knowledge-based economy (Grant, 1996). In a complex world where it is unimaginable to think of actors in isolation, knowledge transfer (KT)[2] has been identified as a crucial process to have access to external information, resources, and agents. Indeed, KT has been considered as one of the main determinants of business success (Tsai, 2001), and the literature has shown how efficient KT can lead to sustainable competitive advantages (Zhang & Zhang, 2018). When a firm becomes a member of a collaborative network, it has easier access to knowledge and, consequently, to strategic resources that could not be accessed without collaboration. Thus, collaborative network is a concept strongly linked to KT (Aalbers et al., 2013; Cabrera-Suárez et al., 2018).

Beyond the academy, policy makers and managers have evidenced this interest by different initiatives for achieving KT through networks. The European Commission has created the Knowledge Valorisation Platform[3] to connect European actors; share best practices, knowledge, and experience; and, consequently, turn research results into innovative practical uses that bring economic value and societal benefits. Another example of the value of KT is the so-called third mission of universities (Baglieri et al., 2018), which is becoming increasingly important. Academics are no longer required only to produce science, but also to be able to transfer it to industry and society. In this sense,

[2] All the acronyms are summarised in the Appendix.
[3] https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/eu-valorisation-policy/knowledge-valorisation-platform_en

some models like the Triple Helix (Etzkowitz & Leydesdorff, 1995) or the Quadruple Helix (Carayannis & Campbell, 2009) have been proposed to analyse KT between agents. The Horizon Europe[4] strategy also seeks to foster the creation of collaborative knowledge networks based on the evidence of the importance of transferring knowledge and generating applications with social and economic impact.

KT has its roots in knowledge management (KM) literature, whose origins date back to the 1960s (Gaviria-Marin et al., 2019). However, it was not until 2000 that the concept of KT was defined (Argote & Ingram, 2000). Despite being a young discipline, the study of KT and its networks has attracted the attention of researchers and practitioners because of its potential influence on strategic decision making at the business and policy levels. As it is still a nascent area, researchers have tried to approach it from multiple perspectives, although most of the attention comes from the study of business management.

Furthermore, bibliometric methods are attracting increasing scientific interest because they make it possible to objectively and quantitatively explore the state of the art of a given discipline from large bibliographic samples. Therefore, they have great potential in examining research prospects and identifying categories of published works (Xu et al., 2021). Although KM has been studied by bibliometrics (Gaviria-Marin et al., 2019), the specific topic of KT and networks has not been addressed yet and constitutes an emergent research area that has been approached from different perspectives, providing some confusion in the literature. As a consequence, our intention here is to develop a bibliometric study on KT and networks with the aim of reaching a better understanding of the discipline. This general objective is specified in three research

[4] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

questions that will be answered through the paper: RQ1. Who are the most influential contributors in the field? RQ2. How has the discipline evolved? RQ3. What are the main emergent research areas, and which are the principal future avenues of the discipline? To do so, this work applies the two basic methods of bibliometrics (Noyons et al., 1999) — productivity analysis and scientific mapping — and makes use of additional techniques such as complex network analysis to enrich the results.

The paper is structured as follows: Section 2 describes the working methodology. Section 3 presents the results of the research (productivity analysis, science mapping, and network analysis). Section 4 summarises the main conclusions, with a special focus on the identification of future lines of research.

2. Methodology

2.1. Data collection

The data source of this study is the Web of Science (WoS) Core Collection. The WoS is an internationally recognised scientific platform among researchers that records high-quality studies and has become one of the main tools for both searching and evaluating different types of publications (Thelwall, 2008). Bibliometric researchers consider the WoS one of the most relevant databases because it provides essential metadata, including abstracts, references, number of citations, lists of authors, institutions, countries, and the journal impact factor (IF).

To obtain our sample, a Boolean search was conducted in June 2021 (see Table 3). With the aim of having complete years and guaranteeing objective comparison between time periods, only documents published between 2000 and 2020 were considered. Based on these criteria, 1,734 papers were identified. Given that our interest is on the organisational level, we focus our selection on the areas of *business* and *management*. In addition, results were filtered by document type and language, selecting only articles written in English to guarantee readability. Our final sample is constituted by 774 studies and 1,788 authors, which were analysed following the two-step bibliometric procedure recommended by Noyons et al. (1999). After that, we enriched our research by using some additional metrics, as Donthu et al. (2021) suggest.

Table 3. Search procedures

		Boolean search	Total publications
1	Keyword search	(("knowledge transfer*" OR "innovation transfer*" OR "R&D transfer*") AND network*)	1,848
2	Index	SCI-EXPANDED, SSCI	
3	Time period	2000-2020	1,734
4	WoS categories	Management AND Business	826
5	Document type	Article	775
6	Language	English	774

Note: Data search was conducted on 19th June 2021.

2.2. Bibliometric analysis methods

Bibliometrics are becoming increasingly popular. If the term "bibliomet*" is searched for in the WoS,[5] about 14,000 results are returned. Furthermore, there has been a three-fold increase in the number of publications indexed in the JCR that make use of bibliometrics in the last five years. This is because it is an objective academic literature review method that provides a comprehensive overview of a particular area of research and allows us to glimpse research trends with the scientific rigour that other techniques lack (Donthu et al., 2021). This popularity is enhanced because it is the only methodology that combines quantitative and qualitative procedures as well as accessibility to scientific databases (WoS, Scopus, PUBMED, Psycoinfo, etc) and specialised bibliometric software (VOSViewer, SciMAT, CiteSpace, BiblioShiny, BibExcel, etc).

[5] The search was conducted in July 2021.

According to Noyons et al. (1999), bibliometrics make use of two main techniques: performance analysis and science mapping. In addition, other enrichment techniques can be used, which go a step further by incorporating network structure metrics (Donthu et al., 2021). The objective of this bibliometric analysis is to show the structural and dynamic aspects of scientific research. The development of computer technologies has allowed this methodology to be improved and positioned as an interesting methodological option to evaluate the structures of science.

Performance analysis uses a wide range of techniques, including word frequency analysis, citation analysis, and counting publications by country, universities, research group, or authors (Thelwall, 2008). Science mapping provides a spatial representation of how different scientific actors are related to one another (Small, 1999). Network analysis complements the previous techniques by giving additional information related to centrality and density metrics (Cobo et al., 2011).

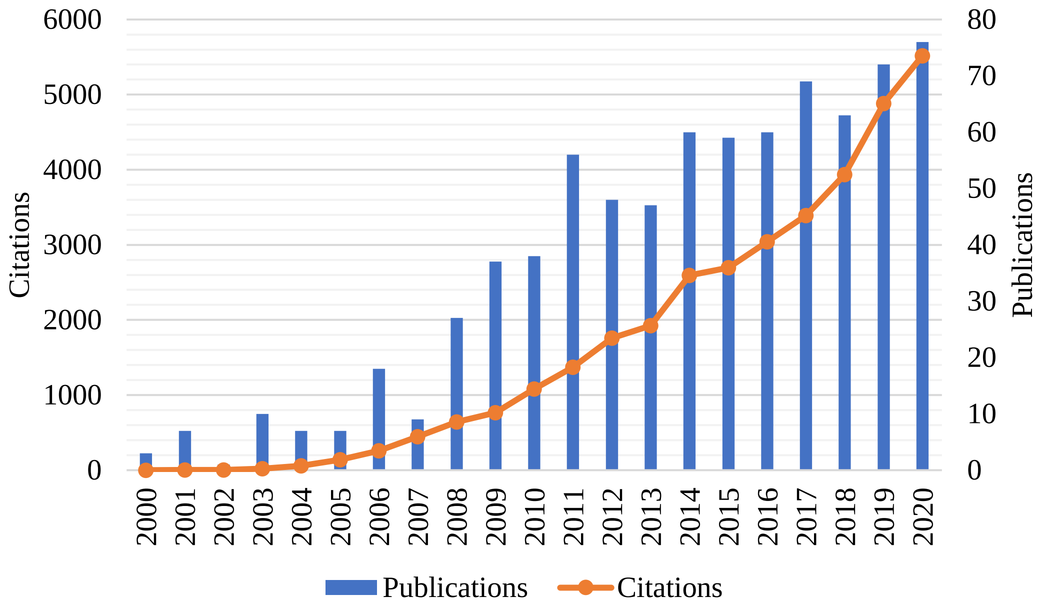
3. Results

This section presents the results of our three-step analysis. First, our performance analysis identifies the most influential journals, authors, and documents within the field of KT and networks. After that, we present the science mapping results. Finally, we use network metrics to enrich the analysis.

3.1. Performance analysis

KT and collaborative networks are a recent research topic that has gained interest in recent years (see Figure 6). Specifically, in 2008 the number of publications tripled that of the previous year and has been growing steadily ever since, reaching the maximum number of articles (n=76) and citations (n=5,519) in 2020.

Figure 6. Publication and citation evolution (2000–2020)



Among the top 20 (actually 21, because of a draw), six journals exceed 1,000 citations. This analysis suggests the existence of a strong heterogeneity of journals that focus on topics such as innovation, international studies, marketing, or human resources, among others. This implies that it is a discipline that receives interest from different fields.

The sources where this research has been published are highly widespread: the 774 articles in this study have been published in 159 different journals. The more frequent journals (11 or more papers) are shown in Table 4. Most of them are leading journals in the business and management fields (the 2020 impact factor [IF] of 88% of the journals exceeds 3.0, with an IF average of 6.1).

Table 4. Top 20 journals according to total publications

	Journal	TP	% TP	TC	Q*	IF
1	*Journal of Knowledge Management*	44	5.69	1,062	Q1	8.182
2	*Organization Science*	28	3.62	4,354	Q2	5.000
3	*Journal of Technology Transfer*	26	3.36	310	Q2	5.783
4	*Journal of Business Research*	25	3.23	679	Q1	7.550
5	*Strategic Management Journal*	23	2.97	2,113	Q1	8.641
6	*Journal of International Business Studies*	21	2.71	1,924	Q1	11.382
-	*Research Policy*	21	2.71	1,597	Q1	8.110
8	*Industrial Marketing Management*	19	2.46	428	Q1	6.960
-	*Knowledge Management Research & Practice*	19	2.46	179	Q3	2.744
10	*International Business Review*	16	2.07	645	Q2	5.915
-	*International Journal of Technology Management*	16	2.07	142	Q4	1.667
-	*Technovation*	16	2.07	869	Q1	6.606
13	*Technological Forecasting and Social Change*	15	1.94	365	Q1	8.593
14	*Journal of Business & Industrial Marketing*	14	1.81	173	Q3	3.462
-	*Journal of Management Studies*	14	1.81	1,309	Q1	7.388
16	*Journal of Management*	13	1.68	267	Q1	11.790
-	*Journal of World Business*	13	1.68	356	Q1	8.513
-	*Management International Review*	13	1.68	357	Q3	3.721
19	*Journal of International Management*	11	1.42	485	Q2	4.645
-	*Management Decision*	11	1.42	191	Q2	4.957
-	*R & D Management*	11	1.42	373	Q2	4.272

*When a journal is indexed in both categories (management and business), the highest quartile is indicated.
TP: total publications; TC: total citations; Q: quartile in the JCR; IF: 2020 impact factor.

The total number of authors in the 774 articles is 1,788. Table 5 identifies authors with four or more contributions. Wilfred Dolfsma and Daniel Levin are the authors with the highest number of contributions (six each), followed by Rob Cross, Zaheer Khan, Yong Kyu Lew, Bill McEvily, and Ray Reagans (five each). According to the number of total citations, Bill McEvily and Ray Reagans are the academics with the highest impact (more than 3,000 citations each) thanks to their seminal work on the structure of networks in KT (Reagans & McEvily, 2003) and the creation of an integrative framework on KM in organisations (Argote et al., 2003), among others. Charles Dhanaraj is very close to 1,000 citations. Next, we found five authors with more than 300 citations (Rodolfo Baggio, Chung-Jen Chen, Ram Mudambi, Marco Tortoriello, and Paul Bierly III).

Another remarkable fact is that 40% of the authors in this ranking are based in Europe (half of them are from Italy), and 32% of the sample comes from North America (28% from the US). This allows us to conclude that the impact of the works in this area is high and that, despite being a global phenomenon, European and American-based researchers are the main leaders on the topic.

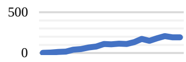
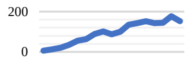
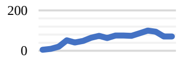
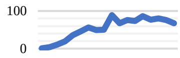
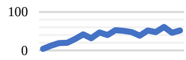
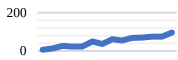
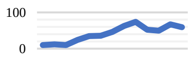
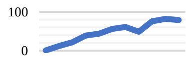
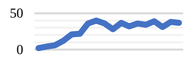
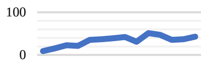
Table 5. Top 21 authors by total publications

	Authors	**TP**	**Affiliation**	**Country**	**TC**	**TC/TP, R**	**h**
1	Dolfsma, W.	6	Wageningen	Netherlands	93	15.5, 20	17
-	Levin, D.Z.	6	Rutgers	U.S.	225	37.5, 13	12
3	Cross, R.	5	Babson College	U.S.	87	17.4, 18	25
-	Khan, Z.	5	Aberdeen	United Kingdom	119	23.8, 17	21
-	Lew, Y.K.	5	Hankuk	South Korea	101	20.2, 18	12
-	Mcevily, B.	5	Toronto	Canada	3,136	627.2, 1	19
-	Reagans, R.	5	MIT	U.S.	3,055	611, 2	16
8	Baggio, R.	4	Bocconi	Italy	315	78.8, 7	19
-	Chen, C.J.	4	National Cheng Kung	Taiwan	523	130.8, 4	8
-	Dhanaraj, C.	4	Temple	U.S.	949	237.2, 3	21
-	Fang, Sc.	4	National Cheng Kung	Taiwan	124	31, 16	17
-	Lee, J.	4	Korea	South Korea	36	9, 21	8
-	Lomi, A.	4	Svizzera Italiana	Switzerland	126	31.5, 15	20
-	Makela, K.	4	Aalto	Finland	294	73.5, 8	16
-	Molina-Morales, F.X.	4	Jaume I	Spain	197	49.2, 10	20
-	Mudambi, R.	4	Temple	U.S.	347	86.8, 5	23
-	Pedersen, T.	4	Bocconi	Italy	173	43.3, 11	35
-	Rabbiosi, L.	4	Copenhagen BS	Denmark	224	56, 9	10
-	Soda, G.	4	Bocconi	Italy	131	32.8, 14	15
-	Tortoriello, M.	4	Bocconi	Italy	333	83.3, 6	10
-	Walter, J.	4	George Washington	U.S.	181	45.3, 12	15

TP: total publications; TC: total citations; R: position in the ranking; h: H index.

Finally, we identify the top 10 most-cited articles (Table 6). Four of them exceed 1,000 citations, and the rest exceed 500. In all cases, they are considered seminal works in the KM stream literature. Tsai (2001) is in the first position of the ranking. This document, which shows that the interaction between absorptive capacity and network position has positive effects on business unit innovation and performance, has settled the bases of the consequences of KT properties. Reagans and McEvily (2003), in the second position, concluded that social cohesion and network range ease KT, over and above the effect for the strength of the tie between two people. Next, Owen-Smith and Powell (2004) demonstrate the importance of considering non-relational features of networks. Geographic proximity and the institutional characteristics of the key agents of a network influence the advantages of the rest. In sum, almost all these works approach KT from a static and structural perspective, trying to understand to what extent network structures influence the processes of knowledge exchange.

Table 6. Top 10 cited publications

	Authors	**Year**	**Title**	**Journal**	**TC**	**TC evolution***
1	Tsai, W.P.	2001	Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance	*Academy of Management Journal*	2,257	
2	Reagans, R.; McEvily, B.	2003	Network structure and knowledge transfer: The effects of cohesion and range	*Administrative Science Quarterly*	1,834	
3	Owen-Smith, J.; Powell, W.W.	2004	Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community	*Organization Science*	1,146	
4	Argote, L.; McEvily, B.; Reagans, R.	2003	Managing knowledge in organizations: An integrative framework and review of emerging themes	*Management Science*	1,097	
5	Hansen, M.T.	2002	Knowledge networks: Explaining effective knowledge sharing in multiunit companies	*Organization Science*	793	
6	Dhanaraj, C.; Parkhe, A.	2006	Orchestrating innovation networks	*Academy of Management Review*	775	
7	Sampson, R.C.	2007	R&D alliances and firm performance: The impact of technological diversity and alliance organization on innovation	*Academy of Management Journal*	608	
8	Volberda, H.W.; Foss, N.J.; Lyles, M.A.	2010	Absorbing the concept of absorptive capacity: How to realize its potential in the organization field	*Organization Science*	596	
9	Uzzi, B.; Lancaster, R.	2003	Relational embeddedness and learning: The case of bank loan managers and their clients	*Management Science*	567	
10	Dyer, J.H.; Hatch, N.W.	2006	Relation-specific capabilities and barriers to knowledge transfers: Creating advantage through network relationships	*Strategic Management Journal*	530	

Note: X axis refers to the period under study (2000–2020).

3.2. Science mapping

To further characterise the subject matter, this section carries out a science mapping analysis of the bibliographic material. Science mapping, as described above, provides a spatial and representative view of how the different actors in a dynamically changing area of knowledge relate to each other (Small, 1999). With the aim of overcoming the limitations of bibliometrics (Tandon et al., 2021), we apply a combination of techniques that enables us to offer a complete overview of the subject. These techniques are bibliographic coupling, co-citation, co-authorship, and co-occurrence analysis (the latter in section 3.3).

We used VOSviewer to analyse patterns of co-citation and co-authorship. VOSviewer calculates the *total link strength* (TLS), which measures the total strength of the links of an item with other items (Vallaster et al., 2019; van Eck & Waltman, 2014). Subsequently, the analysis is complemented by using SciMAT (co-occurrence) for the study of evolutionary dynamics, cluster identification, and analysis of centrality and density of the field under study.

3.2.1. Co-authorship analysis

According to Martínez-López et al. (2018), co-authorship analysis measures the most productive set of documents and identifies units with the highest degree of joint publications, that is, the dynamics of collaboration. It has been shown how the study of co-authorships among academics contributes to richer scientific findings (Tahamtan et al., 2016). Here, collaborating scholars form a network (known as "invisible colleagues") that helps to improve the understanding of a research area (Crane, 1972).

The co-authorship network consists of 12 connected authors forming four clusters (Figure 7 and Table 7). This network reflects few interactions between authors.

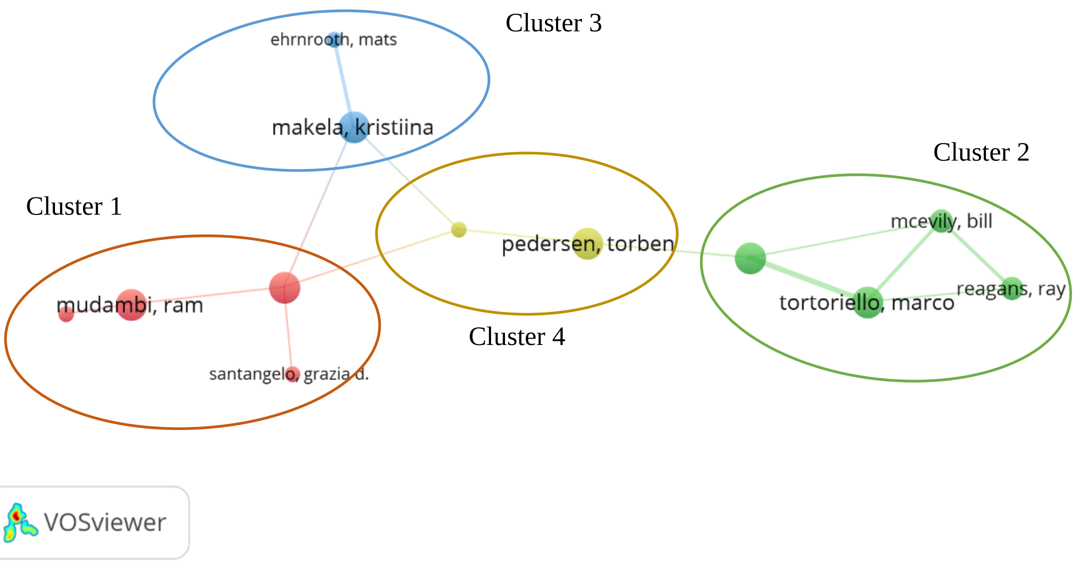
Figure 7 shows how the geographical location of the researchers has a certain influence on the cluster's formation. It can be observed that in three out of the four clusters, there are two authors affiliated in the same country. That means that proximity facilitates co-authorship. If we attend to TLS, Cluster 2 is the one with the highest density in the network mesh. The higher the TLS density, the better the strength of connectivity of this author with the rest of the network. One possible explanation could be because, first, there are the two authors with a higher number of publications in the network, and second, because these two authors are also the ones with the highest number of citations. What is particularly interesting is the position that takes Cluster 4, which acts as a central piece of the puzzle, being the connector of the rest of the clusters.

Table 7. Cluster identification according to co-authorship (authors)

		Affiliation	**Country**	**TP**	**TC**	**TLS**
	Cluster 1 - Red					
1	Buckley, P.J.	Leeds	UK	2	84	1
2	Mudambi, R.	Temple	USA	4	347	2
3	Rabbiosi, L.	Copenhagen BS	Denmark	4	224	4
4	Santangelo, G.D.	Copenhagen BS	Denmark	2	155	1
	Cluster 2 - Green					
1	McEvily, B.	Toronto	USA	5	3,133	7
2	Reagans, R.	MIT	USA	5	3,052	5
3	Soda, G.	Bocconi	Italy	4	131	5
4	Tortoriello, M.	Bocconi	Italy	4	333	6
	Cluster 3 - Blue					
1	Ehrnrooth, M.	Hanken	Finland	2	128	2
2	Makela, K.	Aalto	Finland	4	293	4
	Cluster 4 - Yellow					
1	Minbaeva, D.B.	Copenhagen BS	Denmark	2	167	3
2	Pedersen, T.	Bocconi	Italy	4	173	2

TP: total publications; TC: total citations; TLS: total link strength.

Figure 7. Co-authorship analysis according to authors



Note: Threshold criteria of minimum of two documents; resolution 1.0; 12 of 183 authors are connected.

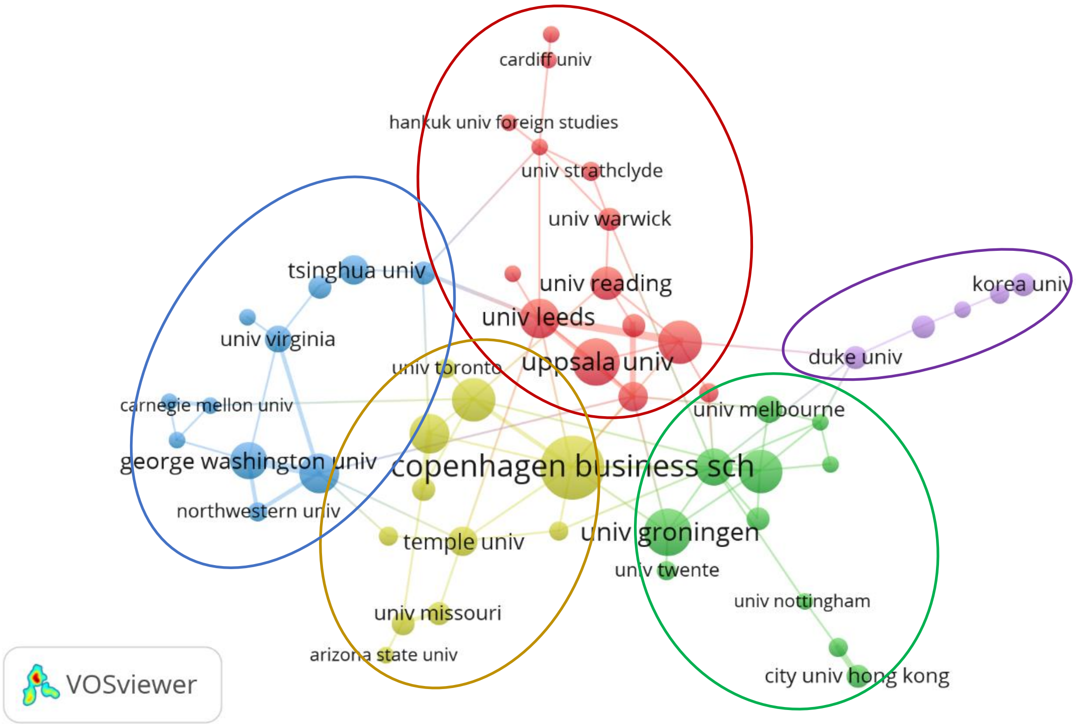
In the case of the co-authorship network by organisations (Figure 8 and Table 8), a higher density in the network is observed. Five clusters were identified, and the top five universities in terms of total publications were selected. Geographically, many co-authorship relations are found in organisations within the same country. In Cluster 1, three of the top five universities are from the UK. According to the TLS, this cluster has a lot of connectivity in the network. Cluster 2 is dominated by Dutch universities, Cluster 3 by USA universities, and Cluster 5 by South Korean universities. Cluster 4 does not allow to see a geographical location path, as it is formed by universities of different countries. This analysis led us to see how universities from northern Europe tend to co-author densely with USA universities and some Asian universities, particularly from South Korea and China.

Table 8. Cluster identification according to co-authorship (organisations)

	Country	TP, R	TC, R	TLS, R
Cluster 1				
Aalto	Finland	9, 5	352, 4	10, 2
Leeds	UK	12, 3	327, 5	13, 1
Manchester	UK	13, 2	618, 1	9, 3
Reading	UK	10, 4	409, 3	4, 6
Uppsala	Sweden	14, 1	309, 6	3, 7
Cluster 2				
Erasmus	The Netherlands	11, 3	1,196, 1	10, 1
Tilburg	The Netherlands	13, 2	544, 3	8, 2
Groningen	The Netherlands	14, 1	307, 7	5, 4
Ljubljana	Slovenia	7, 5	308, 6	2, 9
Melbourne	Australia	8, 4	777, 2	3, 6
Cluster 3				
George Washington	USA	11, 2	411, 5	8, 2
Rutgers State	USA	12, 1	618, 4	11, 1
Tsinghua	China	9, 3	121, 10	2, 8
London	UK	7, 5	384, 6	5, 3
Virginia	USA	8, 4	286, 7	5, 4
Cluster 4				
Bocconi	Italy	13, 2	798, 6	8, 3
Brigham Young	USA	7, 5	1146, 4	5, 6
Copenhagen BS	Denmark	19, 1	1237, 3	11, 1
Insead	France	12, 3	1445, 2	6, 4
Temple	USA	9, 4	1119, 5	6, 5
Cluster 5				
Duke	USA	7, 1	395, 3	4, 1
Korea	South Korea	7, 2	142, 4	1, 5
Seoul Natl	South Korea	6, 4	58, 5	2, 2
Pennsylvania	USA	7, 3	416, 2	2, 3
Yonsei	South Korea	5, 5	536, 1	2, 4

Note: Top five organisations by TP have been selected in each cluster.
TP: total publications; TC: total citations; R: position in the ranking; TLS: total link strength.

Figure 8. Co-authorship analysis according to organisations



Note: Threshold criteria of a minimum of five documents; resolution 0.3; 52 of 879 organisations are connected.

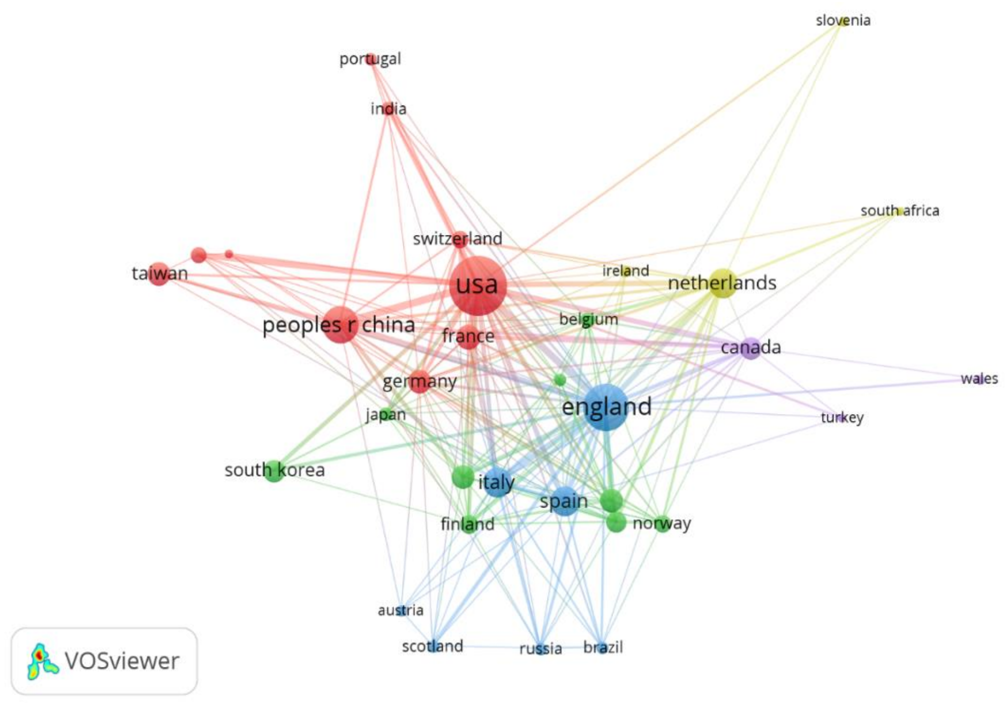
The co-authorship by country (Figure 9 and Table 9) allows for the identification of two large clusters and three smaller ones. This is a quite dense co-authorship network. It should be noted that more than 50% of the countries that have published four or more documents are interconnected with other countries in the network. The countries with the greatest impact on the co-authorship network are the US, UK, and China, as pointed out before. In terms of TLS, Cluster 1, led by the US, is the cluster with the highest density in the network, followed by Cluster 3, led by the UK. Other countries that seem to be very central and well connected in the network are France, Germany, Switzerland (Cluster 1), Italy, Spain (Cluster 3), and the Netherlands (Cluster 4). Clusters 2 and 5 are very dispersed in the network, which implies that although their countries are connected in some way, they do not occupy a relevant role as intermediaries in the field.

Table 9. Cluster identification according to co-authorship (countries)

	TP	TC	TLS		TP	TC	TLS
Cluster 1				**Cluster 3**			
France	40	1,539	36	Austria	8	363	6
Germany	38	1,060	36	Brazil	10	167	15
India	14	337	15	England	143	5,876	139
China	89	1,370	65	Italy	58	2,008	55
Portugal	11	140	6	Russia	10	194	18
Singapore	17	834	18	Scotland	11	598	14
Switzerland	20	544	24	Spain	58	1,618	44
Taiwan	39	1,668	12	**Cluster 4**			
United Arab Emirates	5	76	6	Ireland	9	255	10
US	232	20,679	157	Netherlands	59	2,754	60
Cluster 2				Slovenia	7	308	4
Australia	37	1,483	34	South Africa	6	79	6
Belgium	15	338	22	**Cluster 5**			
Denmark	29	1,775	36	Canada	35	1,598	44
Finland	25	1,154	31	Turkey	5	132	6
Japan	12	271	19	Wales	7	279	4
New Zealand	11	233	17				
Norway	20	1,129	20				
South Korea	34	1,008	15				
Sweden	37	1,067	31				

TP: total publications; TC: total citations; TLS: total link strength.

Figure 9. Co-authorship analysis according to countries



Note: Threshold criteria of a minimum of four documents; resolution 0.75; 33 of 63 countries are connected.

3.2.2. Co-citation analysis

Co-citation analysis identifies occurrences where two articles are jointly cited by one or multiple articles (Shiau et al., 2017). In a co-citation network, two publications are connected when they co-occur in the reference list of another publication (Donthu et al., 2021). The major benefit of this technique is to identify the most influential items. In contrast, since it is based on the number of citations and accumulating citations takes time, this technique has the disadvantage that it is not able to identify emerging research niches or research trends.

Assuming that co-citation analysis helps to identify the most influential documents in a field, we can conclude that the KT literature is based on the understanding of learning networks, absorptive capacity, and the role of social capital in knowledge flows. In this regard, Figure 10 shows a diagram of the reference relationships, and Table 10 identifies the three main clusters that we have labelled "*Structure of collaboration networks*" (Cluster 1), "*Theoretical insights of knowledge*" (Cluster 2), and "*Social capital*" (Cluster 3).

Table 10. Cluster identification according to co-citation (references)

Source	Topic	TC	TLS
Cluster 1: ***Structure of collaboration networks***			
Hansen, M.T. (1999), ASQ	Weak ties	189	1,159
Reagans, R., & McEvily, B. (2003), ASQ	Cohesion and range	186	996
Granovetter, M.S. (1973), AJS	Weak ties	159	912
Uzzi, B. (1997), ASQ	Embeddedness, social structure, and competition	151	853
Granovetter, M. (1985), AJS	Embeddedness in structures of social relations	113	651
Powell, W.W., Koput, K.W., & Smith-Doerr, L. (1996), ASQ	Learning networks	124	651
Ahuja, G. (2000), SMJ	Linkage formation	107	646
Levin, D.Z., & Cross, R. (2004), MS	Weak ties and trust	102	562
Cluster 2: ***Theoretical insights of knowledge***			
Cohen, W.M., & Levinthal, D.A. (1990), ASQ	Absorptive capacity	267	1,224
Tsai, W. (2001), AMJ	Absorptive capacity	213	1,173
Szulanski, G. (1996), SMJ	Stickiness of knowledge	184	972
Kogut, B., & Zander, U. (1992), OS	Knowledge-based theory	151	840
Grant, R.M. (1996), SMJ	Knowledge-based theory	129	681
Lane, P.J., & Lubatkin, M. (1998), SMJ	Absorptive capacity	114	645
Gupta, A.K., & Govindarajan, V. (2000), SMJ	Knowledge flows	122	629
Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y., & Podsakoff, N.P. (2003), JAP	Methods in behavioural research	100	435
Cluster 3: ***Social capital***			
Nahapiet, J., & Ghoshal, S. (1998), AMR	Social capital and advantages	171	949
Tsai, W., & Ghoshal, S. (1998), AMJ	Social capital and value creation	131	872
Inkpen, A.C., & Tsang, E.W. (2005), AMR	Social capital and networks	137	716

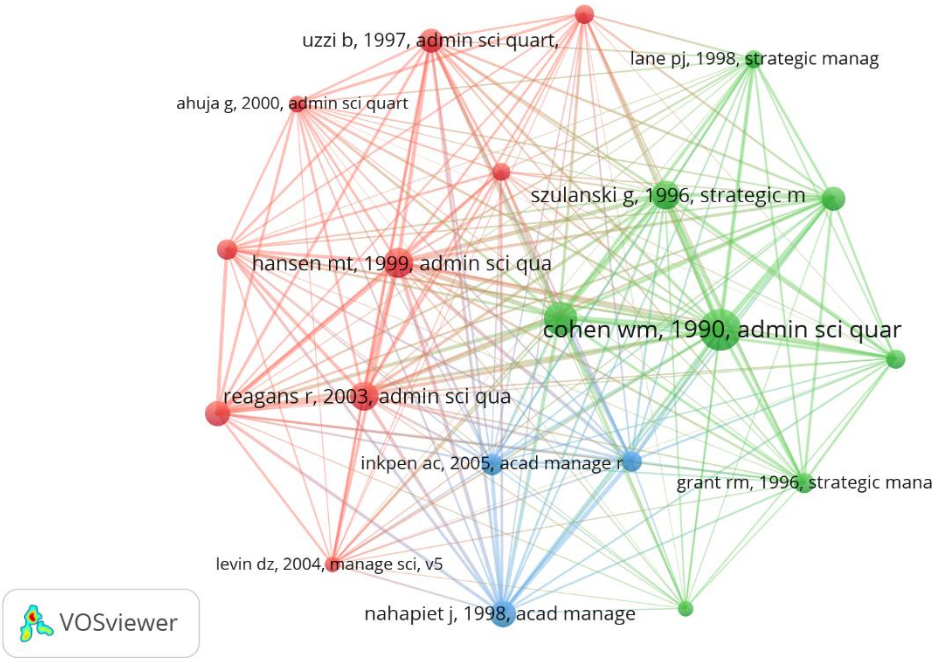
TC: total citations; TLS: total link strength.

The first cluster analyses issues related to the formation of links as well as the study of structural characteristics of social networks. The work of Hansen (1999) presents the largest TLS, followed by Reagans & McEvily (2003) and Granovetter (1973). Powell et al. (1996) identify the importance of learning networks when the industry is knowledge-based, complex, and expanding. Reagans and McEvily (2003) argue that social cohesion and network rank facilitate KT, as they affect the motivation and ability of individuals. Ahuja (2000) finds that firms that possess accumulated technical, commercial, and social capital have advantages for linkage formation, and that firms without such capital have a chance if they generate a radical technological breakthrough. Granovetter (1985) and Uzzi (1997) focus their research on the importance of considering knowledge embeddedness in studies that analyse KT processes from a structural perspective. Finally, Granovetter (1973) demonstrated the cohesive power of weak ties, and Hansen (1999) and later Levin & Cross (2004) found that these ties are helpful for KT, but not when it is complex, since, in this case, strong ties are required.

The second cluster identified is built with papers that focus on the study of knowledge from a conceptual point of view. The papers with the highest TLS are Cohen & Levinthal (1990) and Tsai (2001). Grant (1996) lays the foundations of the knowledge-based theory on which this line of research is based. Kogut & Zander (1992) justify the existence of firms by arguing that knowledge resides in individuals rather than in markets. Szulanski (1996) identifies internal KT barriers, such as the lack of knowledge absorption capacity. In this sense, Cohen & Levinthal (1990) recognise the importance of having the ability to absorb knowledge to generate innovative capabilities. Lane & Lubatkin (1998) reconceptualise the construct of absorptive capacity, achieving greater explanatory power. Gupta & Govindarajan (2000) investigate KT processes in MNEs and find, among other conclusions, that knowledge inputs into a subsidiary are positively associated with the ability to absorb incoming knowledge. Finally, Tsai (2001), in his seminal work, concludes that central units will have a greater capacity to access new knowledge, but this will depend on the absorptive capacity and ability of the units.

Finally, the third cluster, which focuses on the study of social capital, has a lower presence in the network in terms of both the number of documents in the cluster and their centrality in the entire network. All three papers find a positive relationship between social capital and KT. Nahapiet & Ghoshal (1998) conclude that social capital facilitates the creation of new intellectual capital. Inkpen & Tsang (2005) propose conditions to promote KT in three different types of networks based on the dimensions of social capital. Finally, Tsai & Ghoshal (1998) show that social interaction and trust facilitate the exchange of resources and, consequently, product innovation.

Figure 10. Co-citation analysis according to references



Note: Threshold criteria of minimum number of citations of a cited reference: 100; resolution 1.10; 20 of 32,449 documents of the reference list are connected.

3.2.3. Bibliographic coupling

Bibliographic coupling assesses the occurrence of a document reference in the bibliography of two or more publications (Ferreira, 2018). Unlike co-citation analysis, which identifies thematic clusters based on cited publications, bibliographic coupling identifies thematic clusters based on citing publications. Therefore, this technique is especially useful for discovering emerging themes and the latest developments. That is, this analysis can provide a representation of the present state of the research area (Donthu et al., 2021).

Table 11 and Figures 11–13 provide a bibliographic coupling representation. Within each category, the top five contributors have been selected according to the TLS. This analysis, which identifies current research trends, suggests that the study of social capital remains a developing and impactful area of KT literature. Filieri & Alguezaui (2014) conduct a systematic review in which they examine the role that the structure of social capital plays in KT and business innovation, and they find that different types of knowledge and KT processes are the missing links in the relationship between social capital and innovation. Furthermore, they identify how seemingly opposing configurations of social capital are complementary. Therefore, balancing different configurations of social capital will enable knowledge exchange and thus improve innovation outcomes. Maurer et al. (2011), in a widely cited paper, found that KT mediates the relationship between the intra-organisational social capital of organisational members and the growth and innovation performance of the organisation. Other trending topics are related to the mechanisms of knowledge transmission and reception. Khan et al. (2015) found that while formal socialisation mechanisms enhance the understanding and speed of KT to local suppliers, informal ones enhance understanding but not speed. Kang & Hau (2014) concluded that the knowledge receiver's trust in colleagues and the perceived expertise of a sender source positively influences KT.

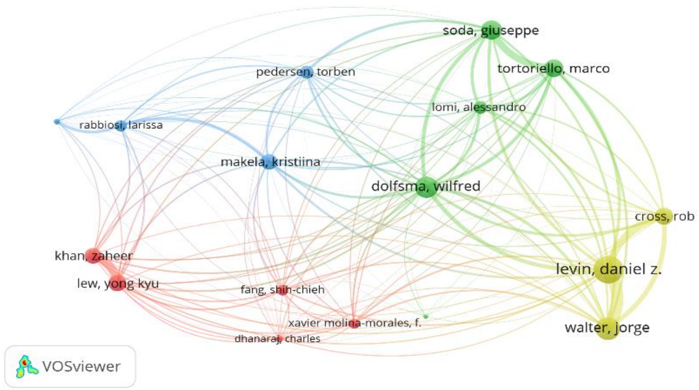
This technique also allows us to identify the origins of the discipline in terms of leading authors. Daniel Levin and Wilfred Dolfsma are the authors with more contributions to the area (6). However, Marco Tortoriello is the researcher with the higher impact (333 citations). Other authors with influence in terms of TLS are Jorge Walter and Giuseppe Soda. Finally, our analysis suggests that the old continent is where the KT and networks research area was born. This analysis seems to be congruent with the results previously discussed in the performance analysis section.

Table 11. Top five bibliographic coupling analysis according to TLS

		TP	TC	TLS
	Document			
1	Filieri and Alguezaui (2014)	-	35	1,629
2	Maurer, Bartsch, and Ebers (2011)	-	177	1,430
3	Khan, Shenkar, and Lew (2015)	-	32	1,226
4	Najafi-Tavani, Giroud, and Sinkovics (2012)	-	41	1,191
5	Kang and Hau (2014)	-	19	1,191
	Author			
1	Levin, D.Z.	6	225	2,870
2	Walter, J.	4	181	2,322
3	Dolfsma, W.	6	93	2,209
4	Soda, G.	4	131	2,010
5	Tortoriello, M.	4	333	1,831
	Institution			
1	Copenhagen BS	19	1,237	11,539
2	Uppsala	14	309	9,239
3	Manchester	13	618	8,448
4	Groningen	14	307	7,805
5	Rutgers State	12	618	7,786

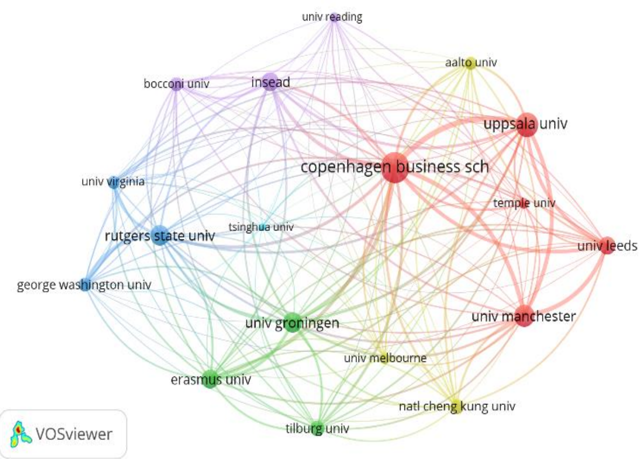
TP: total publications; TC: total citations; TLS: total link strength.

Figure 11. Bibliographic coupling according to authors



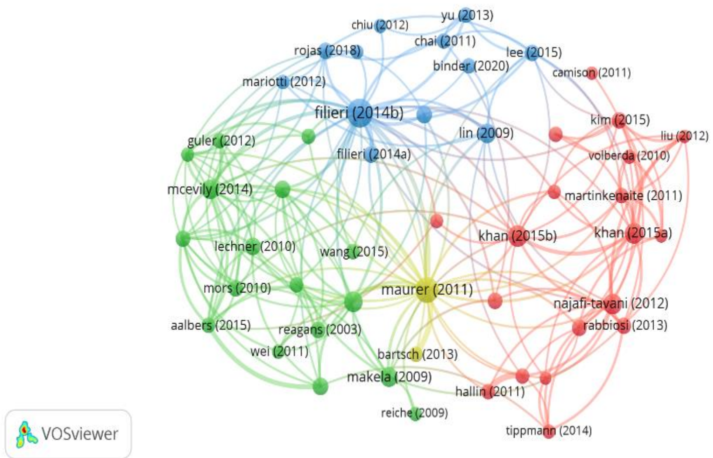
Note: Minimum number of documents: 4; resolution 1.10. 17 of 1,791. Node's size = TLS.

Figure 12. Bibliographic coupling according to organisations



Note: Minimum number of documents: 8; resolution 1.20; 18 of 879. Node's size = TLS.

Figure 13. Bibliographic coupling according to articles



Note: No minimum number of citations required; resolution 1.05; 50 of 774. Node's size = TLS.

3.3. Network analysis

3.3.1. Evolution analysis of the field

We used SciMAT to analyse the topics and thematic areas of the 774 papers included in this study. The initial content analysis counted 2,484 words extracted by the software from the titles and keywords of the complete sample. These words were subsequently evaluated and standardised by the research team in a laborious process. For instance, words like “MNEs”, “MNCs”, and “multinationals” are judged to be the same construct. After the standardisation and grouping process, 309 unique keywords were retained. To analyse the evolutive dynamics of the field and following the previous literature, we break our sample into four five-year periods (the first one, with a small volume of existing works, includes six years). Figure 14 provides a preliminary picture of the evolution of the field. Each column represents a period and identifies a series of nodes that are groups of keywords. These keywords are connected through links of different types. The continuous links represent high intensity between terms. In addition, the thicker the links, the higher the co-occurrence of keywords. The discontinuous links represent the relation between the concepts with lower intensity. Finally, nodes’ size is determined by the *H-index*. Note that accumulating citations requires time, so the size of the bubbles is sensitive to this, which explains their greater size in the first periods.

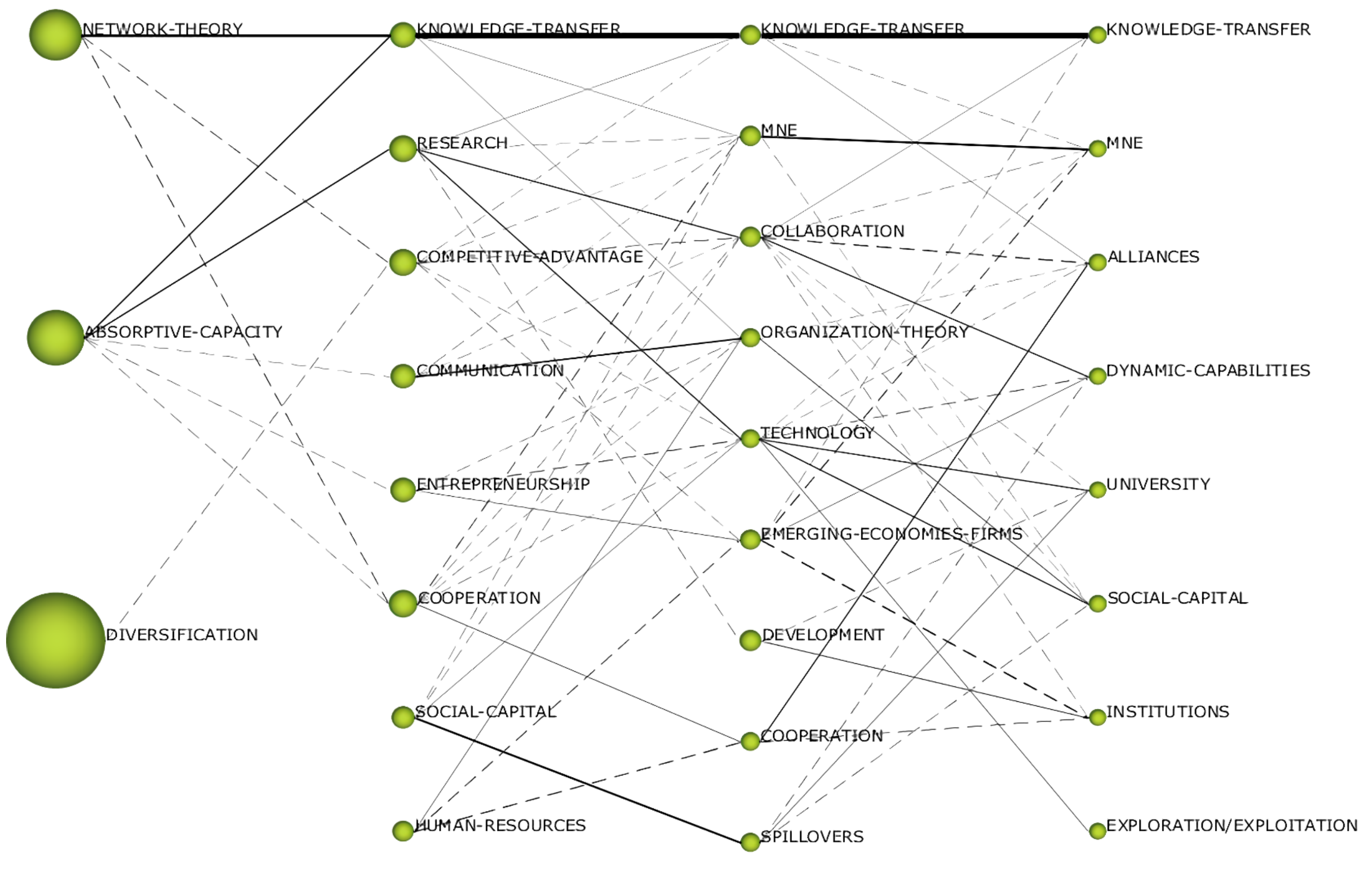
In the first stage *(2000–2005)*, academia was concerned with the study of network theory, strongly linked to KT in the following periods (Reagans & McEvily, 2003), as well as with concepts such as absorptive capacity (Chen, 2004; Tsai, 2001) and diversification (Breschi et al., 2003). Although diversification shows a large H-index, it is hardly connected to the rest of the concepts. In contrast, absorptive capacity constitutes, together with network theory, the origin of the KT discipline.

It is from the second period *(2006–2010)* when the term *KT* gains impact. In addition, other concepts such as human resources (Shaw & Williams, 2009), competitive advantages (Bou-Llusar & Segarra-Ciprés, 2006), entrepreneurship (Filatotchev et al., 2009), and communication (Joshi et al., 2007) emerged. Absorptive capacity, a key concept in the previous period, is strongly linked, besides to KT, to the concept of research (Vega-Jurado et al., 2008). Social capital emerged without being linked to previous concepts (Rottman, 2008), but with a strong impact in the following periods. In the third tage *(2011–2015)*, the focus is placed on several items like MNEs (Mudambi et al., 2014), the dynamics of collaboration (Hewitt-Dundas, 2012), technology (Alexander & Martin, 2013), cooperation (Clausen, 2013), and spillovers (Kalapouti and Varsakelis, 2015), among others. Social capital from the previous period is now strongly linked to spillovers (Galunic et al., 2012) and communication, which was a concept with high impact between 2006 and 2010, and is linked to organisation theory (Hecker, 2012). However, if we focus on the continuous line from the origin, research is in this third period with collaboration and technology (Bozeman et al., 2013).

In the last period (*2016–2020)*, terms such as MNEs continue to be widely used, but other constructs emerge. The term cooperation from the third period is strongly linked to alliances (Korbi & Chouki, 2017) and collaboration to dynamic capabilities (O'Reilly et al., 2019). Also, technology is linked to university (Nilsen & Anelli, 2016), social capital (Al-Tabbaa & Ankrah, 2016), and ambidexterity (Sengupta & Ray, 2017). To sum up, if we focus only on the path built by the continuous links, which represent the strongest interaction between terms, we can see how the discipline has evolved from the study of absorptive capacity to the study of technology and collaboration and, finally, to dynamic capabilities, universities, social capital, and ambidexterity. These concepts are hot topics in the current literature.

Figure 14. Group of keyword evolution map (by co-occurrence)

1st period (2000–2005)	2nd period (2006–2010)	3rd period (2011–2015)	4th period (2016–2020)



Note: Bubble size is determined by H-index. The greater the intensity of the ties, the more co-occurrence of groups of keywords between periods.

3.3.2. Clustering and network properties

Following Cobo et al. (2011), Figure 15 represents in different strategic diagrams the evolution of the area considering a three-dimensional space: centrality (X-axis), density (Y-axis), and the average number of citations (size of the themes).

Centrality measures the degree of interaction of a network with other networks (Callon et al., 1991) and can be defined as: $c = 10 \times \sum e_{kh}$, where k is a keyword belonging to a given topic and *h* a keyword belonging to other topics. Centrality measures the strength of external ties to other topics. We can read this value as a measure of the importance of a topic in the development of the entire research field. Density measures the internal strength of the network (Callon et al., 1991) and can be defined as: $d = 100 \left(\sum e_{ij}/w\right)$, with i and j keywords belonging to the theme and w the number of keywords in the topic. Density represents a measure of the cohesiveness of a network, and it is commonly measured as the proportion of existing connections over the total number of possible connections in a network.

Four kinds of themes (clusters) can be identified according to the quadrant in which they are located (Cobo et al., 2011). Themes located in the upper-right quadrant can be considered as the motor themes. They are related externally to concepts applicable to other themes that are closely related. Those themes are well developed and important for the structuring of the research field. Themes in the upper-left quadrant are very peripheral and specialised, so they have marginal importance for the field. Themes in the lower-left quadrant represent either emerging or disappearing themes. Finally, themes in the lower-right quadrant are important for the field but are not developed enough. Thus, this quadrant groups transversal and general basic themes.

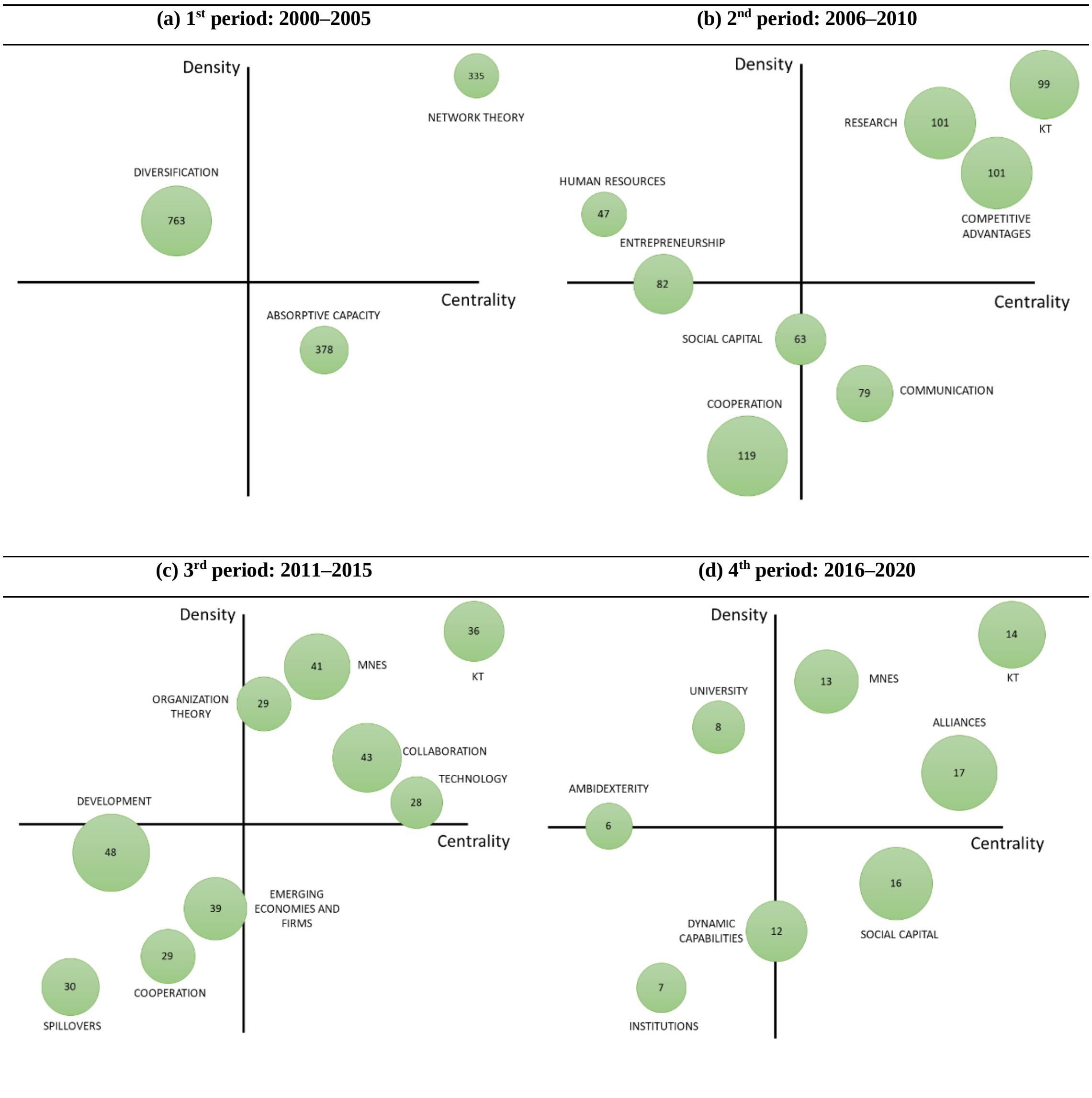
First period (2000–2005). Consistent with the previous point, three concepts are identified (see Figure 15a). Two of these themes can be considered key due to their contribution to the field growth: network theory (motor theme) and absorptive capacity (transversal theme). Given the novelty of the subject matter, this period is evidenced by very general terms, which attempts to lay the theoretical foundations of the discipline.

During the *second period (2006–2010)*, eight themes are identified and displayed in the strategic diagram (Figure 15b). Among them, KT, research, and competitive advantages are considered as key due to the quadrant in which they are located (motor themes). This is the first time that the cluster KT appears in the analysis, so it can be considered as the moment where the discipline emerges. This second period is focused on the understanding of basic concepts in relation to knowledge flows, such as the consequences in terms of competitive advantages, research, or entrepreneurship. Communication is a transversal theme in this period, in which social capital also attracts researchers' attention. During this period, research on cooperation was impactful (119 citations on average), followed by the motor themes.

Third period (2011–2015). Continuing with the analysis, in this period (Figure 15c) nine themes are identified, but with a different distribution and themes in comparison to the previous period. It is relevant to notice that there are no transversal or peripheral themes identified in this period. Four concepts (besides KT) are considered motor themes: MNEs, collaboration, technology, and organisation theory. Here, the field seems to be oriented toward an international and interorganisational context. Also, the field is likely to have an innovative and technological focus.

Finally, in the *fourth period (2016–2020)* eight research themes can be identified (Figure 15d). Apart from KT, alliances (with the highest number of average citations) and MNE clusters represent the motor themes in these last years. It is important to highlight that in this period KT is analysed from an institutional and dynamic perspective (both emerging themes). Ambidexterity seems to also be an emerging theme related to KT research. That makes us think that KT still focuses on innovation literature. Social capital, which was identified in previous periods, is now showing high centrality but low density, which means that it can be classified as a transversal topic that continues reflecting attraction. Finally, research into universities is also contributing to the KT field, but in a peripherical way due to its specificity.

Figure 15. Strategic diagrams based on co-occurrence of keywords (by periods)



4. Discussion and conclusion

Emerging research topics

To sum up, it is worthwhile to mention that in the last five years, academia has shown special interest in more complex issues and methods (Huarng et al., 2021), together with others that have been maintained over time. Regarding the expected future avenues of the discipline, we can identify the following:

- *Multi-unit companies*: There is a large body of literature that tries to understand how knowledge flows interact within the firm (Hansen, 2002). However, our work has shown that, in recent years, there has been an increased focus on the analysis of inter-firm KT (Latorre et al., 2017; Vatamanescu et al., 2020). Improving the understanding of KT between companies with geographically dispersed business units is of particular interest given the current dynamics and needs of the industry (Kolympiris & Kalaitzandonakes, 2013). The levels of rivalry (Hallin & Lind, 2012) to which companies with dispersed units are exposed, as well as the dynamics of market technological and economic development, force them to engage in learning processes in order not to be left behind (Teigland & Wasko, 2009). In addition, these companies are influenced by different factors than single-unit companies that can affect KT practices. Cultural distance (Blomkvist, 2012), communication strategies (Fawad Sharif et al., 2020), and leadership style (Mabey et al., 2012) are some of the most interesting variables to study.

- *New business models*: Globalisation and digitalisation have led to the development of new business models, most of them based on information technologies (IT). Organisations must fight with disruptive technologies and be prepared for change. As a result of this adaptation, the value of a company is created through digital assets that lead to new business models (Cassetta et al., 2020). There is not much research in this line, but recent literature (Eggers et al., 2022) insists on the need to deepen our knowledge about new business models. Given their intrinsic characteristics, KT processes can be very different from those already studied. As Bianchi and Mathews (2016) suggest, IT can contribute to reducing the distance and overcoming the commercial barriers between organisations by providing an additional channel for creating new relationships. Innovation is crucial in these organisations; therefore, being part of collaborative networks that facilitate access to external agents and resources is key (Malhotra & Temponi, 2010; Sanders, 2005). Future research may seek to characterise KT processes and strategies in these new business models, what consequences information exchange processes have on firms, how they differ from traditional firms in terms of structural determinants and characteristics, and what technologies are necessary to produce efficient KT.

- *Complex ecosystems*: In a knowledge-based economy, with many interconnected actors, the value of KT is vital (Cabrera-Suarez et al., 2018; Dung et al., 2021). The study of these flows, considering that they occur only between private organisations, is limited. Recent literature has shown interest in the study of ecosystems from a holistic perspective, considering that there are multiple types of agents involved (Carlisle et al., 2013). Among others, large scientific centres (BSC) (Ferrer-Serrano et al. 2021) — i.e., universities and research organisations — play a relevant role in knowledge-based ecosystems, as they are the main engine of knowledge generation. It is also important to consider that there are other agents in the context with an important supporting role in complex ecosystems, such as public administrations (Zou & Ghauri, 2008) and society (Carayannis & Campbell, 2009). This, together with the fact that the business literature is very interested in the institutional perspective (Bendickson et al., 2020), makes this analysis very attractive for future research.

- *Social capital*: Our analysis has highlighted the strong interest in the analysis of social capital. Social capital theory has been applied to KT from both individual and organisational perspectives (Bartelt et al., 2020), providing a framework to explain this process along three dimensions: structural, relational, and cognitive capital (Chiu et al., 2006). According to previous research, social capital is a central axis to explain KT as it is a process that relies on social relationships and community connections (Bartelt et al., 2020; Choi, 2016). Li et al. (2021) identify the need for future work to jointly analyse all three dimensions to find out the real effect of social capital on KT. In addition, future studies may explore the different degrees of the effect of the dimensions of social capital in new business models.
- *Changing cycles*: Industries are dynamic and KT is an active process that requires time. Static approaches were very useful in the early stages of KT research, when the field was so underdeveloped that structural concepts were necessary to understand it (Gupta & Govindarajan, 2000; Lane et al., 2001). In contrast, current research requires longitudinal data, which seem to be strongly linked to the study of dynamic capabilities. Organisations have adaptative routines and processes to cope with market demands (Irwin et al., 2022) and turn strategic capabilities into sustainable competitive advantages (Teece & Lazonick, 2002). Their KT requires mechanisms of acquisition, emission, absorption, assimilation, recombination, and integration (Ferrer-Serrano et al., 2021). Thus, having dynamic capabilities can help to facilitate KT processes, make them more efficient, and even transform them into economic and innovative business results (Castellano et al., 2021).
- *Ambidexterity*: There is no doubt that innovation is supported by learning, and the absorption of new knowledge leads to change and innovation (Caiazza et al., 2021; Lin et al., 2013). In contrast, the effect of KT dynamics on ambidexterity has not

been studied in detail. Although there are some studies suggesting how KT can be a good driver of innovation ambidexterity since it enables knowledge sharing and access (Cabeza-Pullés et al., 2020; Fu et al., 2018), there is no evidence showing how KT practices in collaborative networks facilitate innovation by exploring and exploiting at the same time. In this sense, we believe that further studies on the behaviour of the ambidextrous firm that actively participates in KT processes can serve to exemplify practices that can shed light on this underexplored avenue of research.

Conclusion

This study intended to provide a comprehensive and rigorous overview of the last 20 years of KT and networks through a bibliometric approach. For that purpose, we carried out performance analysis, science mapping, and dynamic network analysis. This allows us to identify the key contributors of KT and network literature. This paper has also set up the question of how the discipline has evolved since its origin. Our analysis has revealed that, first, the evolution of the field provides an approximation that shows how it is a hot research area that is gaining a lot of attention in recent years. Second, the complementary network analysis let us interpret the evolution of the field through the evolution of the most important keywords and their interrelation. In this sense, the field has evolved from a more strategic and corporate level to a more dynamic and institutional one. That is, KT research interest has evolved from a theoretical, micro, and structural perspective (object research) to a practical, macro, and complex perspective (context research).

KT will have to face great challenges due to the dynamism of the field. The present study can help both scholars and practitioners who are approaching this topic and want to have a comprehensive overview of the scientific literature. Moreover, scholars can leverage the results of this study to address future studies better, considering the proposed avenues for future research. At the same time, policy makers and practitioners could find a useful baseline to foster the development of collaborative strategies that enable KT processes. However, this study is not free from limitations. First, the dataset was collected through the WoS to obtain higher-quality results. However, this choice limited the number of publications. In addition, some exclusion criteria were imposed to improve the performance analysis, which also limited the final sample. Moreover, some indicators can lead to inconsistencies when used to compare different publications or authors. Hence, each indicator should be read together with the other ones, for example the h-index. Another limitation is that the WoS count system attributes more importance to articles with multiple authors or affiliations compared to articles appearing with a single author, although the scientific mapping performed with VOSviewer allows, at least partially, to neutralise this limitation (Gaviria-Marin et al., 2019). Still, it would be of interest to use other software that can deliver complementary information. Finally, to provide better comparability and achieve better alignment to the research questions of this study, only the business and management fields in the WoS were chosen as a unit of analysis. Each of these limitations thereby provides opportunities for future work for academics, researchers, and practitioners.

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Appendix I

	Acronym	Description
1	TP	Total papers
2	TC	Total citations
3	Q	JCR 2020 Quartile
4	h	H index
5	IF	Impact Factor
6	TC/TP	Citations per publication
7	R	Position in the ranking
8	KT	Knowledge transfer
9	MNEs	Multinational enterprises
10	TLS	Total link strength
11	R&D	Research and development
12	KM	Knowledge management
13	JCR	Journal Citations Report
14	JIF	Journal Impact Factor
15	BSC	Big Science Centres
16	IT	Information Technology

Study 2

Deepening the understanding of knowledge transfer and networks' foundations: Future research lines and challenges

1. Introduction

Knowledge transfer (KT) has been considered as one of the main determinants of business success and innovation (Tsai, 2001; Werner et al., 2015). Some research has even shown how efficient KT can generate sustainable competitive advantages (O'Connor & Kelly, 2017; Zhang & Zhang, 2018). To this end, the creation and use of collaborative relationships offer access to valuable knowledge and KT processes (Hemmert, 2019; Tallman & Chacar, 2011). In other words, the generation of collaborative networks is a concept strongly linked to KT processes.

Although the concept of KT has been object of debate for a long time, it is just in the last years that academia has put the focus on this issue. Researchers have tried to provide an answer to questions such us which are the antecedents that determine a greater and better propensity to transfer knowledge (Kaminski et al., 2008; Levin & Walter, 2019), what consequences in terms of innovative performance behaviour KT offers (Mariotti, 2011; Villasalero, 2013), or how different ecosystems and contexts affect the willingness to generate networks for KT (Frenz & Ietto-Gillies, 2009).

Literature has shown that the determinants and the effects are not the same for every KT collaboration process. Specifically, KT has been examined both in intraorganizational networks (Kim et al., 2014), that is, between units in the same firm; and in interorganisational networks (Maggioni et al., 2011; Malsch & Guieu, 2019) i.e. between different organisations. Multinational enterprises (MNEs) have received a lot of attention given the interest in analysing knowledge flows between subsidiaries and headquarters (Claver-Cortés et al., 2018; Nadayama, 2019). Literature also has revealed the importance of promoting relationships with institutions that create knowledge such as universities (Chen et al., 2019) and with institutions that facilitate learning processes such as public institutions (von Malmborg, 2004).

However, even that KT and collaborative networks have been approached from multiple perspectives, there is a need to deepen on this debate with the aim of advancing towards a systematization of the theoretical and empirical findings on the topic.

To provide a comprehensive literature overview, a systematic review was carried out using the Web of Science (WoS) and Scopus databases to identify relevant publications over a 20-year time frame (2000-2020). To ensure the quality of the sample selected, only papers published in journals classified in the first two quartiles of the Journal Citation Report and specifically in the areas of “business” and/or “management” were included. This search process allowed for the analysis of 190 high impact research studies.

This study aims to contribute to the literature by answering these questions: 1. *What are the main conceptual findings of the studies focusing on KT analysis and collaborative networks?* 2. *What does the literature say about the antecedents, determinants, and effects of KT on the innovative and thus, business performance?* 3. *What role different contexts and institutions play in the processes of knowledge dissemination?* 4. *What are nowadays the main research gaps and upcoming research trends?*

Our work adds to existing research in three important ways. First, we provide the first systematic review of KT and collaborative networks. We objectively identify the studies with the greatest scientific impact to present a comprehensive overview of the current state of the art related to KT processes. Our approach allows us to identify and distinguish the effect of KT on different collaborative networks and business typologies. Secondly, we identify aspects that are less researched, providing a direction for future research and identifying upcoming trends. Specifically, we identify five areas with great projection in future research. Finally, we provide several implications of interest for academia, policy makers and public policy.

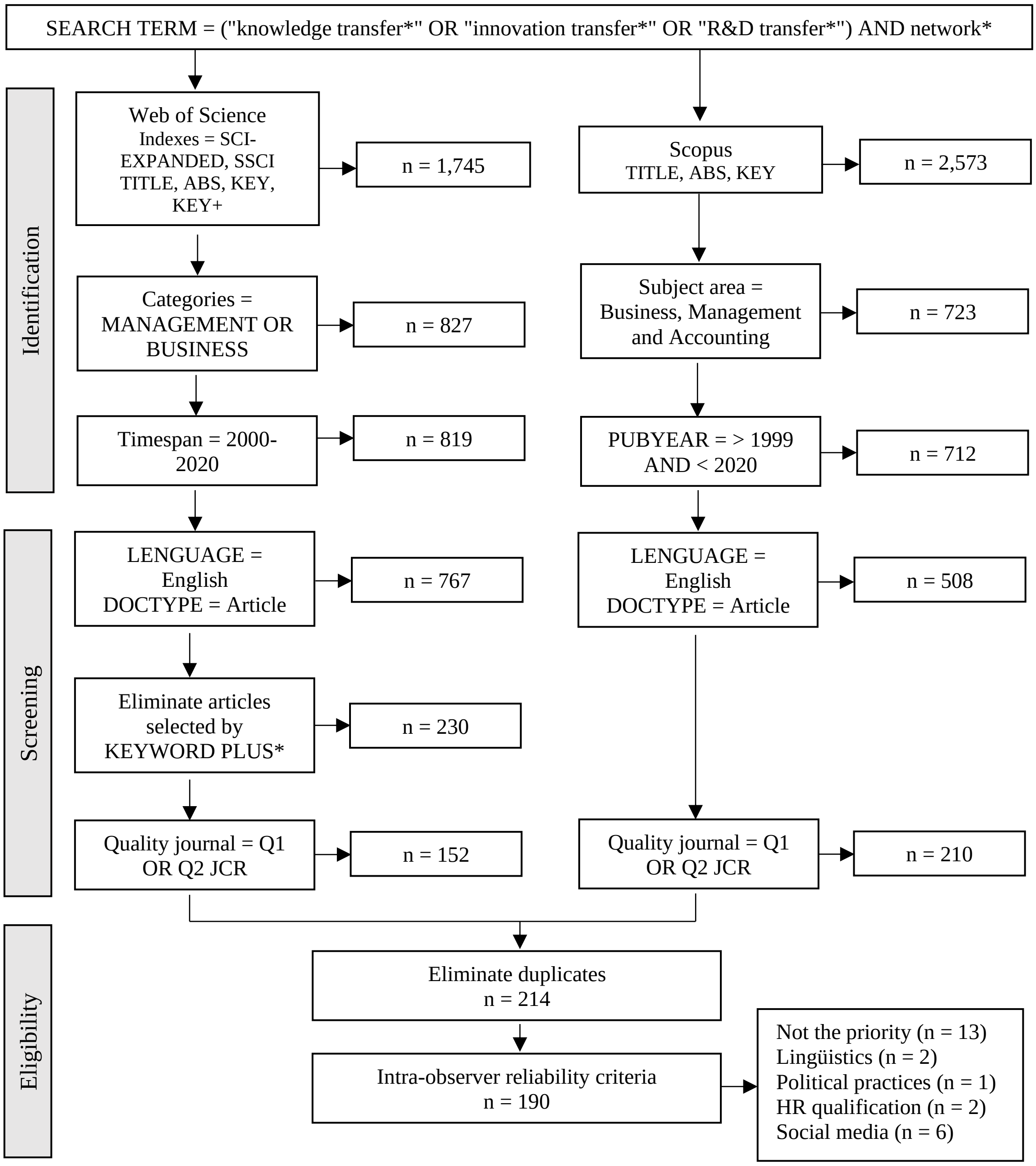
This work is structured as follows: Section 2 presents the methodology, the screening criteria and the sample obtained. Section 3 discusses the findings obtained after an exhaustive examination of the papers under study. Finally, section 4 presents the conclusions, implications, future research agenda and limitations of the study.

2. Methodology

In this research, a systematic review of the literature was applied. This method is considered a valuable tool to provide a holistic view of existing research on a specific topic to improve its understanding and conceptualization (Booth et al., 2016; Carayannis et al., 2021; Tranfield et al., 2003). With the support of this research method, we can identify and analyse a significant sample of published articles related to KT and its networks, thus providing a comprehensive overview of this topic.

Following the procedures outlined in Tranfield et al. (2003), the systematic review was conducted in a three-stage procedure. To better represent the research search process, we present Figure 16, which was developed following the PRISMA guidelines developed by Moher et al. (2009). These steps are explained in further detail in the following subsection. After that, the sample description is presented.

Figure 16. PRISMA diagram of the systematic literature review



Note: Search process was done on January 1st, 2021.

2.1. Sample selection, screening, and eligibility

First, according to previous systematic literature reviews (Foss & Saebi, 2017; Sivarajah et al., 2017) two scientific search engines, the WoS (Web of Science) and SJR (Scopus), were used to identify appropriate publications. It is widely recognized that these two databases include the most relevant, impactful, and up-to-date peer-reviewed academic publications. The search was conducted on January 1st, 2021.

The search and screening processes were similar in both cases. The Boolean search was performed on the titles, abstracts, keywords, and keywords Plus. The latter refer to those articles that have received citations from other works that do use the terms we have searched. Since in this study we are strictly interested in research that analyses our keywords, we exclude the articles that WoS has selected according to the keywords Plus. This obstacle does not appear in the case of Scopus. The categories selected are Management and Business (in the case of Scopus, the area also includes Accounting), and the period under analysis covers the last 20 years.

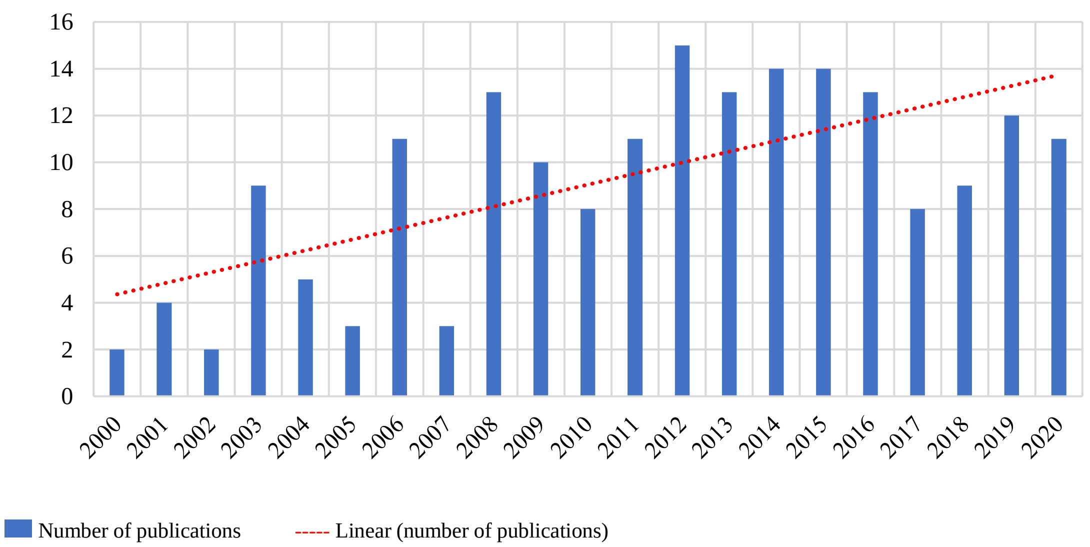
To further guarantee objectivity, only documents that have been published in journals were included, thus excluding book chapters or documents published in conference proceedings. We restricted our search to articles published in English. At this point of selection, we apply one quality criterion. We include articles published in journals indexed in quartiles 1 and 2 of the 2018 JCR and SJR. In this way, the conclusions we draw will be based on high quality and impact publications.

After that, duplicate investigations were eliminated. Finally, the criterion of intra-observer reliability is followed to eliminate articles that do not fit with the objectives of our search. All the abstracts were read, as well as several introductions and conclusions, to determine with greater robustness the exclusion or inclusion of the articles of our sample. The key criteria for inclusion were the following: that "knowledge transfer" and "networks", or their derivatives, appear as central pieces of the article, that "knowledge" appear to be nominally linked to innovation, and that "networks" appears to be nominally linked to collaboration. 24 articles were removed because they do not fit the requirements. 13 use the terms in a collateral way, 2 analyse different aspects of the linguistics, 1 focus on political recommendations, 2 linked knowledge with qualification processes of the human resources departments and 6 use networks followed by social media (Facebook and Twitter among others). 190 articles across 53 journals met the inclusion criteria. These 190 articles were read in their entirety for the final analysis and synthesis.

2.2. Sample description

Figure 17 shows the number of articles published in each of the years considered in our sample. Even though it is a path that presents multiple peaks throughout the period, the trend is upward. If we pay attention to the first years, the number of publications is, with some exceptions, quite low (usually between 2 and 5 publications per year). However, when one advances in the timeline, the publication trend gains strength. Between 2008 and 2016, the number of articles ranges from 8 (2010) to 15 (2012). This increase in publications on innovation transfer may be due to the publication of the national innovation surveys that contribute to the European CIS in 2001, 2005, 2007, 2011, 2013 and 2015 (Dziallas & Blind, 2019). Despite the decrease in publications in 2017 and 2018, in 2019 and 2020, the trend seems to continue growing. This suggests a clear interest in the subject.

Figure 17. Number of publications (2000-2020)



Note: Boolean search for this research was conducted on January 1, 2021.

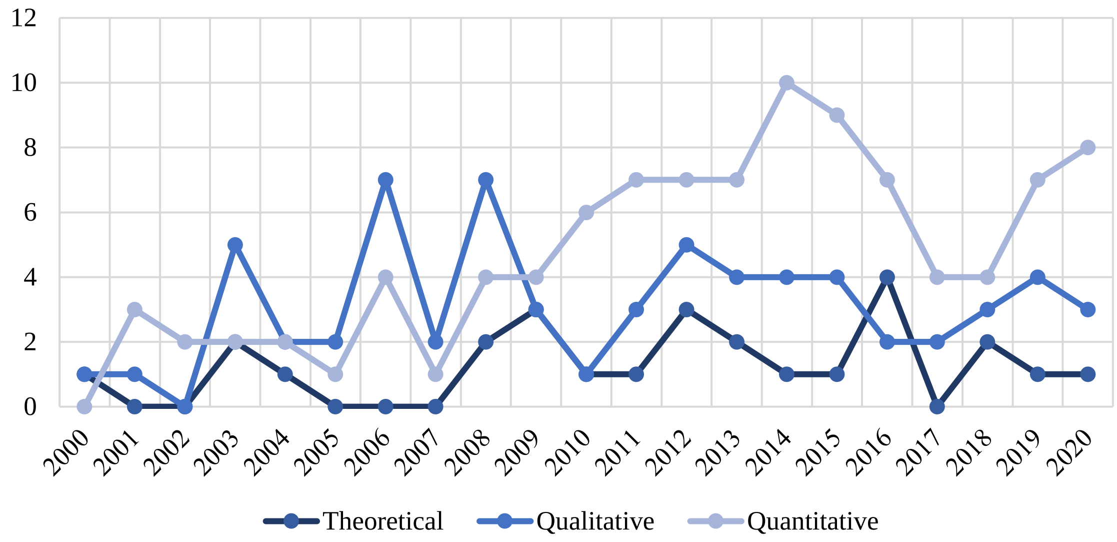
Figure 18 shows the number of publications per journal. Most of the articles have been published in the Journal of Knowledge Management (JKM), specifically almost 20% of the publications under analysis. Other journals that show interest in this research are Journal of Technology Transfer (JTT), Research Policy (RP), Journal of Business Research (JBR) and Organization Science (OS).

Figure 18. Paper distribution according to the journal in which there are published

Note: In addition, 6 journals published 3 papers that fit the inclusion criteria, 10 journals published 2 and 20 published 1.

In terms of research method, most studies apply quantitative research methods (52.11%), which peaked in 2014. Qualitative methods (34.21%) dominate the first stage of the period studied (2002-2008). In contrast, in the second stage (2010-2020) there is a clear preference for the use of quantitative techniques. In this sense, even though articles using quantitative methods seems to be the trend, the four previous years this type of research suffered a significant decrease, with the number of publications very close to those using qualitative techniques. Purely theoretical articles, which have been considered as an independent category, have remained low over time, although there has been a slight increase in the interest in publishing research of a theoretical nature. This may be because all quantitative articles need a solid theoretical support behind them, which on many occasions are obsolete in time. Figure 19 illustrates these results.

Figure 19. Evolution of the papers published according to the research method (2000-2020)



If attention is paid to the scope of study of qualitative and quantitative articles (theoretical works have been suppressed for the elaboration of this statistic), there is a tendency to research at country level (see Figure 20).

Figure 20. Evolution of the papers published according to the scope level (2000-2020)

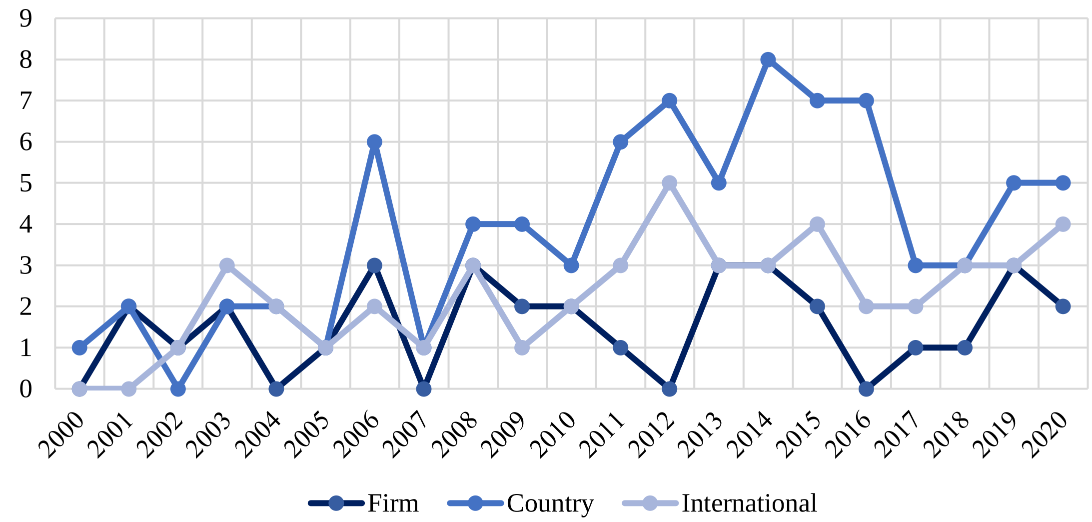


Table 12 combines figures and percentages on the research method, either qualitative or quantitative. In both cases there is a remarkable preference for country analysis. However, this preference is significantly higher in the case of research whose methodology is quantitative. As noted above, this may be due to the greater accessibility to databases in each region by researchers. In the case of qualitative works, the study of a single company and the use of international databases does not present great differences. On the other hand, there is a greater tendency to use international data in articles whose methodology is quantitative. Specifically, 34.77% of the studies carried out at country level (n = 85), are based on samples from the United Kingdom (17.65%) and the United States (14.12%). China (11.76%) and Spain (8.24%) rank third and fourth, respectively. Regarding the aggregated data by continent, research based on European data accounts for more than half of the total (51.76%). Asia (27.06%) and America (18.82%) follow.

Table 12. Synthesis of the articles analysed

Research method	**Scope level**	**Number of papers**	**%***	**%****
QL	Firm	16	50	9.76
	Country	30	36.59	18.29
	International	18	37.50	10.98
QT	Firm	16	50	9.76
	Country	52	63.41	31.71
	International	30	62.50	18.29

Localization		**Number of papers**	**Localization**		**Number of papers**
America (n = 16)	United States	12	Europe (n = 44)	United Kingdom	15
	Brazil	3		Spain	7
	Canada	1		Sweden	6
Asia (n = 23)	China	10		Italy	5
	South Korea	3		Germany	3
	Taiwan	3		France	2
	Pakistan	3		Austria	2
	India	2		Ireland	1
	Israel	1		Finland	1
	Arabia Saudi	1		Belgium	1
Africa	South Africa	1	Oceania	New Zealand	2

*Percentage represented by the different fields of study (Firm, Country or International) over each research method (QL or QT).
**Percentage represented by the different fields of study (Firm, Country or International) over the total number of articles analysed (n = 162; since the theoretical ones are not counted in this statistic).

3. Findings

To achieve a better understanding of the findings of this systematic review, the arguments have been organised around two sections. The first one groups the main theoretical concepts and relationships that focus on the KT process through collaborative networks. The second section presents the applied results found in this review. This section is structured in three sub-sections articulated around the concept of collaboration.

3.1. Conceptual foundations of KT and collaborative networks

According to the knowledge-based view (KBV), knowledge is a strategic asset capable of generating successful innovations and competitive advantages (Grant, 1996; Inkpen & Tsang, 2016; O'Connor & Kelly, 2017). However, to achieve this, collaborative complex networks that facilitate the absorption and exchange of tacit and explicit knowledge are necessary (Aalbers et al., 2013; Cabrera-Suárez et al., 2018; Uzzi & Landcaster, 2003; Wang, 2013). In other words, KT must be produced (McGuinness et al., 2013). In this way, beneficial strategic effects created (Villasalero, 2014) are no strangers to the organisational culture and industrial ecosystems (Jakob & Ebrahimpur, 2001). Several studies based on the findings of Tsai (2001) have revealed that the interaction between knowledge absorption capacity and position in the collaboration network significantly affects the innovation and performance of business units (Chen & Hung, 2010; Fleming & Marx, 2006; Villasalero, 2013). They also warn that an improvement in the absorption capacity and an expansion of the network is fundamental to the achievement of competitive advantages (Malik et al., 2012; Streb, 2003; Zhang & Zhang, 2018). These ideas have been supported by subsequent studies that have allowed a more detailed analysis of the relationships (see Figure 21).

Accessibility to collaborative knowledge does not necessarily guarantee its integration (Hardy et al., 2003; Liu & Hart, 2011; Villasalero, 2017) and its innovation success (Andersson et al., 2015). In order to achieve adequate integration and avoid the so-called problem of knowledge stickiness based on the difficulty of knowledge movement (Szulanski and Jensen, 2006), the literature points to the motivational disposition of the units involved, the inherent properties of knowledge (Andersson et al., 2015), an intense interaction among the actors of the network, and the development of solid links among them (Kang & Hau, 2014; Moreira et al., 2018; van Wijk et al., 2008). Only after determining the best combination of network links, valuable knowledge can be effectively transferred between dispersed units (Schleimer & Riege, 2009). In this respect, intermediary agents and boundary spanners (Merminod & Rowe, 2012; Tortoriello et al., 2012) play a key role in facilitating knowledge flows (Jiang et al., 2019; Major & Cordey-Hayes, 2000) through the creation of structured and motivated collaborative networks (Tasselli, 2015; Tóth & Lengyel, 2019). Therefore, the intermediary roles in KT processes should be occupied by actors with high responsibility (Kim et al., 2014) and coordination level (Patriotta et al., 2013).

There is consensus that social relations play a relevant role in the exchange of knowledge. The sustainability of collaborative networks requires strong links to facilitate the knowledge flow (Bennet & Bennet, 2008; Reagans et al., 2015; Zhou et al., 2010). Given its difficult exchange, high motivation is needed to transfer tacit knowledge. Consequently, close and strong social ties are required to achieve efficient transfer (Bae & Koo, 2008; Hemmert, 2019; Reagans & McEvily, 2003; Weber & Weber, 2011). To achieve strong ties, interpersonal trust among network actors is an important variable, becoming identified in the literature as one of the main predictors and drivers of KT's collaborative networks (Levin & Walter, 2019; Massaro et al., 2019; van Wijk et al., 2008). Other variables that the literature has positively related to KT are firm size (Kolympiris & Kalaitzandonakes, 2013; van Wijk et al., 2008), strategic orientation

(O'Connor & Kelly, 2017), effective leadership (Mabey et al., 2012), co-creation of values (Lee et al., 2008), sense of identification with values (Liu et al., 2018; Lomi et al., 2014; Najafi-Tavani et al., 2012, 2014), previous experience (Kaminski et al., 2008; van Wijk et al., 2008) and geographical scope (Kolympiris & Kalaitzandonakes, 2013). Finally, although KT seems to be hampered when cultural distance is high, there is evidence that companies with experience in dealing with diverse cultures can better overcome such difficulties (van Wijk et al., 2008).

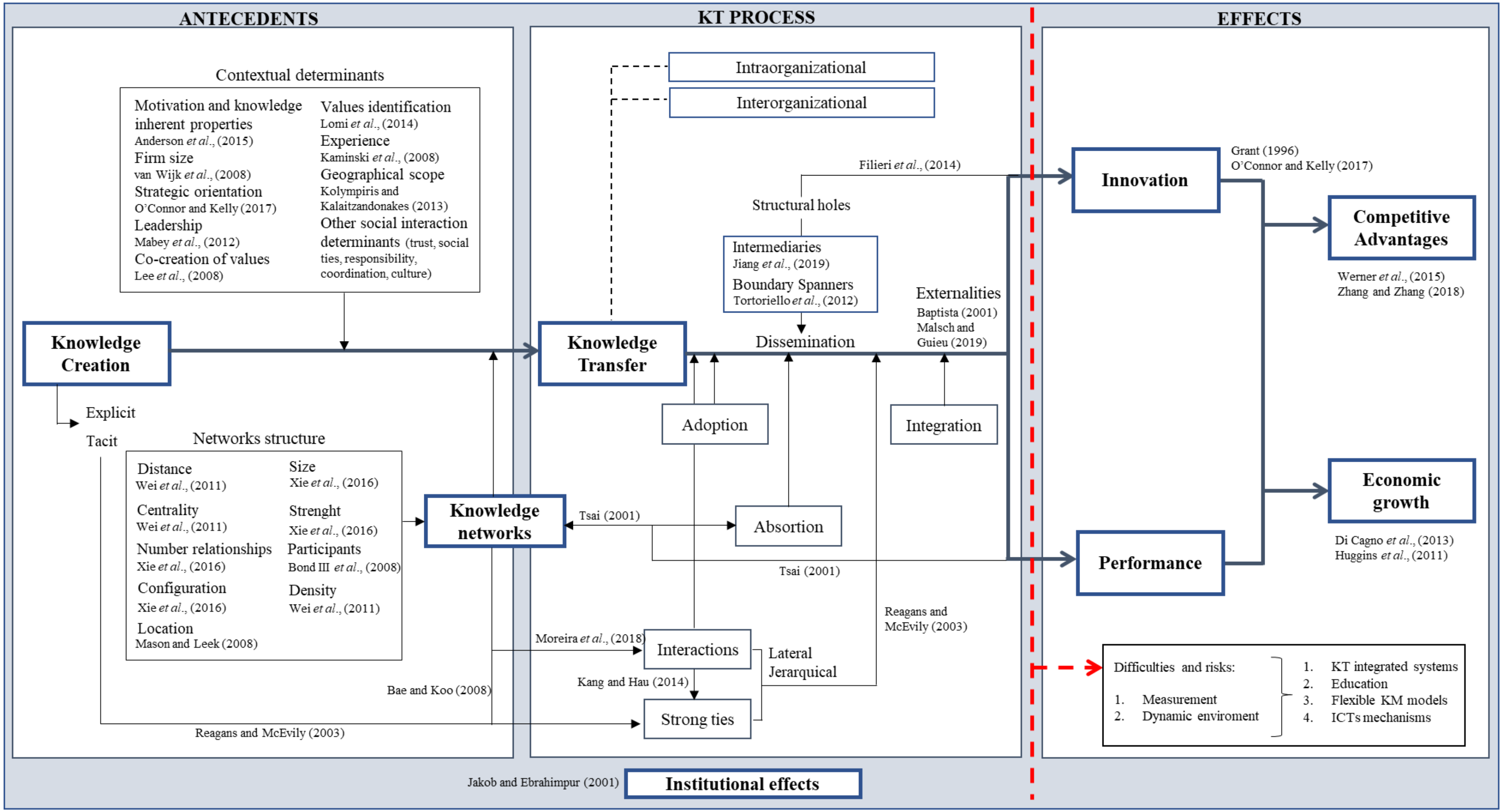
To achieve a better understanding of the KT, network structure has to be analysed (Breschi & Catalini, 2010; Dyer & Hatch, 2006; Ozkan-Canbolat & Beraha, 2015; Ye et al., 2020). Innovation requires the availability of new knowledge, but its accessibility depends on different network structure factors such as agents' location (Mason & Leek, 2008; Singh et al., 2016) and links structure and composition (Ghosh and Rosenkopf, 2015). Some specific variables that impact positively in the performance and commitment of the KT (Tortoriello et al., 2012) are the number of relationships (Xie et al., 2016), centrality (van Wijk et al., 2008; Wei et al., 2011), size, strength and heterogeneity of the network (Xie et al., 2016) and the correct identification of participants (Bond III et al., 2008). Agents with lower distance and more equivalent position to the knowledge source tend to have a higher KT. Network density mitigates the negative effect of distance (Wei et al., 2011). Several studies have pointed out how apparently opposite configurations in collaborative networks complement each other, i.e. dense networks, and structural holes (Filieri & Alguezaui, 2014) concluding that having structural holes in collaborative networks can be considered a driver of effective KT (Panetti et al., 2020; Reagans & McEvily, 2003) and innovation (Filieri et al., 2014).

KT through interorganisational networks has attracted academic attention given its implications (Martin & Salomon, 2003; Werr et al., 2009). In this sense, literature points out how KT networking among organisations promotes externalities that, in turn, generate innovations (Baptista, 2001; Malsch & Guieu, 2019) and real impact on regional competitiveness, depending on the organisational characteristics of the network (Huggins et al., 2012; Owen-Smith & Powell, 2004). In these networks, trust is fundamental specially in periods of uncertainty (Tsai, 2001; Tsouri, 2018) so the selection of partners requires careful attention (Knudsen, 2007). The study of KT's determinants in inter-organizational networks has aroused special interest. Thus, the R&D investment level of the knowledge receiving region, the size of the organization or region, the financial infrastructure, the scientific culture and the similarity of its productive systems (Fang et al., 2013; Ghauri et al., 2016; Maggioni et al., 2011) determine the creation and maintenance of KT's interorganisational networks. However, although complementary knowledge is positively associated with innovative performance, too much complementarity can lead to dispersed knowledge and its consequent fragmentation (Knudsen, 2007).

Literature has not overlooked the study of intra-organisational networks as they can be more dominant than interorganizational networks (Kim et al., 2014) and, moreover, can be a source of competitive advantage for the organization (Hansen, 2002; Tallman & Chacar, 2011). Common organizational values (Cao et al., 2016; Schillebeeckx et al., 2016), operational proximity (Tagliaventi & Mattarelli, 2006), personal and informal ties (Levine & Prietula, 2012; Pyka, 2000), job satisfaction (Fliaster & Schloderer, 2010), non-hierarchical communication structures (Guechtouli et al., 2013) and commitment (Teigland & Wasko, 2009) are the most common positive and impactful determinants found in this literature stream. Also, a few studies found a positive effect of employee mobility in organisational learning (Corredoira & Rosenkopf, 2010) given the increased creativity (Lovejoy & Sinha, 2010) and labour performance (Cao et al., 2016) of agents whose mobility is frequent. In this sense, mobility motivation should be an important task for responsible managers given its expected positive effect (Anne Crowne, 2009; Kumar, 2013). Both KT through inter-organisational and intra-organisational networks are discussed in more depth in the following section.

Despite these arguments, KT complexity generates difficulties (Alkhuraiji et al., 2016; De Bruyn et al., 2020; Herschel et al., 2001; Poorkavoos et al., 2016; Sorenson et al., 2006) and risks (Dutton et al., 2014; Mariotti, 2011; Trkman & Desouza, 2012) mostly associated to its measurement (Argote & Fahrenkopf, 2016) and to the fact that environments are dynamic (Levine & Prietula, 2012). Effective knowledge management processes and the development of a common language considerably reduce risks (Chang et al., 2012; García-Pérez et al., 2015; Marabelli & Newell, 2012; Pezzillo Iacono et al., 2012). KT integrated systems can exploit synergies, avoid confusion and preserve knowledge (Hutzschenreuter & Horstkotte, 2010; Sherif et al., 2006). Education also plays an important role in managing and promoting KT practices (Hofer-Alfeis, 2008; Iddy, 2020; Zhao et al., 2004). In this sense, the developing of comprehensive (Schlegelmilch & Chini, 2003), complex (Johnston et al., 2006) and flexible (Spring, 2003) models through ICTs (Carayannis et al., 2006; Peng et al., 2014) can facilitate the strategic importance of KT.

Figure 21. Conceptual framework



3.2. KT and collaboration between firms and other agents

This second section synthesis the main empirical findings that derive from the review performed. The main conclusion is that collaboration is the main driver of KT. With the aim of providing a clearer picture of the literature that analyses this issue, we organise our review into three subsections. The first one considers the relationship that are establish within a company or between different firms. We distinguish between KT that takes place within different units of a MNEs and the knowledge that can be transferred as a consequence of interfirm alliances. Our second section analyses the role of universities as key agents in the process of KT. Finally, we asset the relevance of the institutional environment as a facilitator of KT.

3.2.1. KT within and between companies

As mentioned previously, this section has been structured in two sub-sections in order to provide a better understanding of the arguments. The first one identifies KT within a company, focusing on collaboration between subsidiaries in MNEs. The second one is devoted to collaboration between firms, i.e., firm alliances.

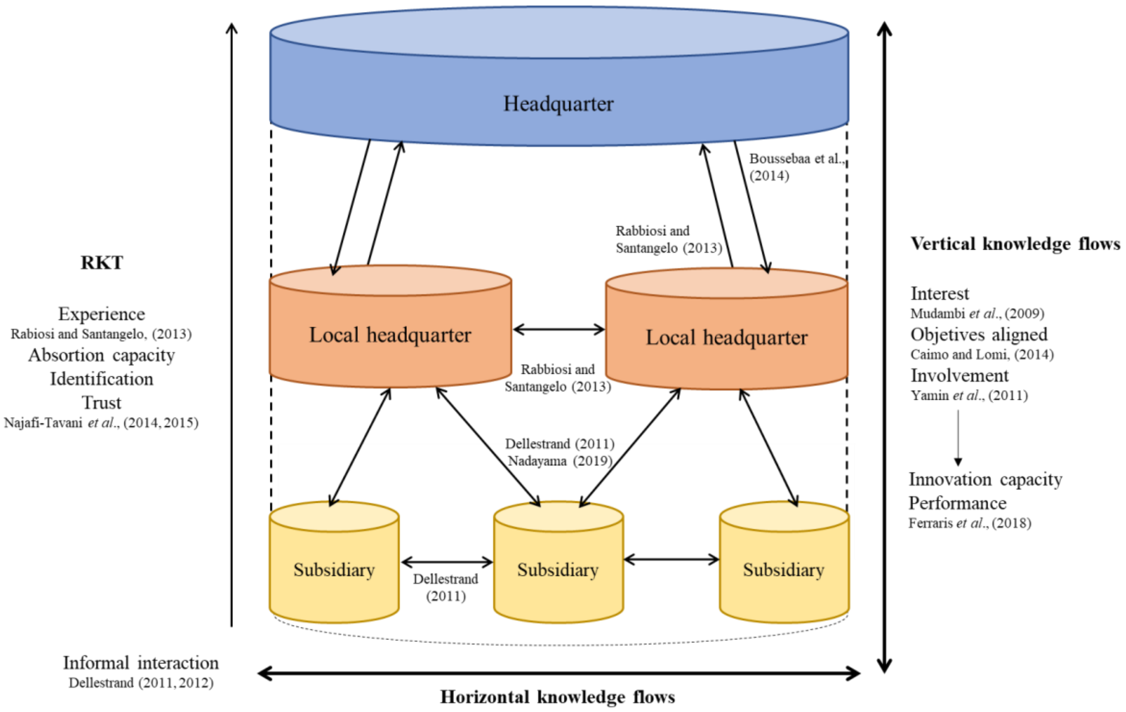
KT within companies: Intrafirm collaboration

Literature has paid wide attention to the study of KT between business units within a company, especially in MNEs, where given their intrinsic characteristics, collaboration is vital. The integration of MNEs in collaborative networks had been linked with a greater innovation capacity and performance (Ferraris et al., 2018; Hallin et al., 2011; Lee et al., 2010; Li & Lee, 2015; Nadayama, 2019). Moreover, this relationship is enhanced when the objectives of network actors are aligned, reciprocal (Caimo & Lomi, 2015; Lomi et al., 2014) and exists real interest in implementing KT practices (Mudambi et al., 2009).

The directionality of knowledge flows in these companies has been subject of debate (see Figure 22). Vertical KT, i.e., between headquarters and subsidiaries, has been linked to benefits in self-learning and performance (Boussebaa et al., 2014; Najafi-Tavani et al., 2014, 2015). This is enhanced with experience of the subsidiary, especially when the direction of KT is upward (Rabbiosi & Santangelo, 2013). Achieving internal integration of reverse knowledge transfer (RKT), i.e., vertical, and upward flows, requires knowledge absorption capacity, adequate identification of relationships and trust among the actors involved (Isaac et al., 2019; Mudambi et al., 2014; Najafi-Tavani et al., 2014, 2015). In addition, the RKT effects are greater in high-tech and knowledge-intensive industries and in countries with a higher competitiveness index (Nair et al., 2015). When knowledge flows horizontally (Boussebaa et al., 2014; Noruzi et al., 2018), either between local headquarters or between lower-level subsidiaries, informal interaction (Dellestrand, 2011, 2012; Harzing & Noorderhaven, 2006) is vital. Direct involvement of headquarters helps lateral KT, but it is necessary to align subsidiary's interests with firm corporate strategy (Yamin et al., 2011). Anyhow, local headquarters have access to the needs of the firm and can adapt the knowledge of the subsidiaries to make it useful and transferable to others (Lunnan & Zhao, 2014).

But these findings should be interpreted with cautiousness. Contextual factors such as market mechanisms, technological turbulence (Lee et al., 2008) competitive pressure (Hallin & Lind, 2012) and cultural and linguistic distance (Harzing & Noorderhaven, 2006) need to be considered as they have been identified in the literature as KT barriers in MNEs collaboration networks. There are also industry factors that should be considered. The way KT relationships are established, the economic incentives and the organisational characteristics of firms will influence the networked collaboration structures (Dellestrand & Kappen, 2012; Tregaskis, 2003). So, achieving the full potential of KT in MNEs requires an understanding of the needs and resources available (Dellestrand, 2011). However, while some authors find that coordination and monitoring mechanisms (Claver-Cortes et al., 2018) can provide networking opportunities (Kumar, 2013; Li & Lee, 2015; Miao et al., 2011), Lind and Kang (2017) identify a negative moderating effect of affiliate headquarter supervision on KT related activities.

Figure 22. MNEs knowledge flows



KT between companies: Interfirm alliances

Literature has also looked at KT between business structures based on collaborative alliances. Those structures provide access to external knowledge that enable the development of new knowledge and networked learning opportunities (Paswan & Wittmann, 2009; Vătămănescu et al., 2020). In other words, these alliances can generate knowledge bridges across borders (Khan et al., 2015). This requires mechanisms for receiving, systematising, and managing knowledge to overcome the limits of knowledge diffusion (Zhao et al., 2005) by avoiding undesirable spillovers. Although the relationship between KT in alliances and improved economic performance has not been conclusive in the literature (Beamish & Berdrow, 2003), it has been shown that the strategic value generated in alliances networks turns into a greater innovative capacity (Harryson et al., 2008; Inkpen, 2005; Verspagen & Duysters, 2004). This has generated interest in identifying the most important mechanisms and determinants for efficient KT in alliance networks.

The establishment of quality relationships i.e. strategic partnerships with adequate channels of communication, trust and commitment, either with external or internal alliance actors, allows the creation of effective collaborative learning networks (Fawad Sharif et al., 2020). To access to quality partners and, therefore, knowledge flows, business units' network position represents an essential determining factor that will define the outcome of alliances learning careers (Szulanski & Jensen, 2006, 2008; Walter et al., 2007). But the KT network requires stability to create long-term synergies and potential innovations that will benefit the performance of the collaborative alliance. To increase the stability of the learning network and be able to take advantage of opportunities for knowledge recombination, literature points to the need of reducing cultural barriers. To this end, building relationships with partners that share similar cultural and organisational objectives is essential (Johanson et al., 2020). In this way, relationships can be strengthened and, consequently, the stability of the network of collaborative alliances can be enhanced (Faems et al., 2020; Rottman, 2008). Another determinant of alliances KT refers to the co-opetition mechanism. This is especially useful when there is a clear alliance orientation and numerous partners. Although it requires a broad set of external resources, Bouncken and Fredrich (2016) suggest to young companies the use alliance networks to take advantage of co-opetition and to gain inlearning.

3.2.2. Universities as key agents in KT

Literature has traditionally identified universities (producers of ideas and knowledge) and firms (users of knowledge) as the two essential elements of the innovation system (Seibert et al., 2017). More importantly, collaboration between these two agents (Chen & Lin, 2017; Novelli et al., 2006; Rubin et al., 2015; Thomas, 2012) build up the central axis to achieve innovation (Knudsen, 2007; Miller et al., 2016) and regional economic growth (Fuster et al., 2019). If the collaborative interaction fails, the innovation system can become fragmented, which is particularly pernicious when it is composed of SMEs with limited access to external knowledge (Koschatzky, 2002). According to recent studies, university-industry collaborative KT networks should be promoted (Ferrer-Serrano et al., 2021; Mao et al., 2020) given the development necessities of each industry and region (Fuster et al., 2019).

Commercialising scientific knowledge depends on different industrial and academic factors that limit university-industry collaboration. Previous experience in KT and interpersonal links between universities and industry play a vital role in generating collaborations (Hemmert, 2019; Krabel & Mueller, 2009). Specifically, the universities' ability to generate and transfer knowledge depends on tangible factors such as economic support, administrative and contractual tasks, and also on intangible factors such as research quality, recognition, respect, ethics, and support from research groups networks (Cabeza-Pullés et al., 2020; Hewitt-Dundas, 2012; Rosli et al., 2018).

However, there are obstacles that can hinder KT between the two main agents of an innovation system. There are socio-cultural reasons that influence effective KT from universities to industry such as the particular social norms of a region (Mabey et al., 2015). The physical distance between companies and universities (Spithoven et al., 2021; Petruzzelli, 2008) coupled with the lack of efficient ICT systems (Bathelt et al., 2011;

Wakefield, 2005) also difficult knowledge flows. Padilla-Meléndez et al. (2013) focus on identifying barriers to KT from the researcher's perspective. They found how the lack of awareness of the research groups capabilities, the bureaucratic hurdles and business' perception of scientific knowledge low transferability are the most common barriers.

One of the suggestions derived from our review is to create collaborative environments between universities and industry. In this sense, commitment and willingness of companies to ensure open communication flows can help (Rosli et al., 2018). In addition, Fischer et al. (2020) suggests that universities should strengthen internal ties between members of the academic community for the joint generation and dissemination of useful knowledge for frugal innovations. They also pointed that reducing bureaucratic barriers with external agents, as well as setting up incentive schemes that reward involvement, are critical for success. Finally, it has been shown that international scientific mobility fosters the development of new relationships. As a consequence, supportive mobility programmes of researchers facilitate the exchange of knowledge between regions (Gibson & McKenzie, 2014; Murakami, 2014; Guo et al., 2018). In this regard, the role of public institutions is important as is discussed in the following section.

3.2.3. The role of the institutional context

This literature emphasises the role played by the institutional context in the understanding of the KT drivers (Filatotchev et al., 2009). Collaboration between public institutions and innovation system actors (i.e., big science centres and industry) is a key element that facilitates KT and the only way to enable the development of specific long-term initiatives (Carlisle et al., 2013; Gerstlberger, 2004; Novelli et al., 2006), especially in knowledge-based economies (Miller et al., 2016). Public institutions, which can play the role of knowledge banks or knowledge brokers (von Malmborg, 2004), can influence KT processes and thus the R&D capability of a firm or region (Zou & Ghauri, 2008). This influence depends, among other factors, on the contextual economic and political characteristics (Jandhyala & Phene, 2015). In this sense, there is evidence of a positive and direct relationship between countries with high levels of R&D expenditure and the capability to generate and transfer knowledge (Di Cagno et al., 2014).

As economies develop and national institutional support is not enough, there is a necessity to generate cross-border networks to facilitate learning (Khan et al., 2016). Governments' legal, economic and administrative commitment and support facilitate innovation through KT (Khan et al., 2016; Millar & Choi, 2009; Novelli et al., 2006). The creation of incentives, the implementation of measures to stimulate knowledge flows and to increase the absorptive and managerial capacity of business networks (Koschatzky, 2002), are some of the mechanisms that literature has identified as useful. It is also necessary to develop informal networks to share knowledge across national borders (Levin & Barnard, 2013; Ko & Liu, 2017). Thus, the creation of collaborative inter-organisational KT networks involving public institutions, research centres and industry can help to gain regional legitimacy and contribute to a sustainable territorial competitive advantage (Zou & Ghauri, 2008).

All this brings challenges. At the regional level, improving the regional image can allow harnessing social capital. Moreover, by creating attractive environments and generating local, national, and international linkages, the development of collaborative communities is encouraged (Smedlund, 2006). At the national level, the creation of a national knowledge agenda for strategy and policy development (Schneider, 2007) provides a clear roadmap to stimulate collaborative networks that will enhance the government innovation ecosystem (Di Cagno et al., 2014).

4. Conclusions

Through a comprehensive review, this paper aimed to examine the current state of the literature on KT and collaborative networks. To this end, a systematic review was conducted over the last twenty years following the PRISMA method. Specifically, 190 articles from 53 journals were considered. This review has detected a growing interest in KT and collaborative networks research, especially from a quantitative and macro perspective.

After a thorough review, we conclude that previous literature has placed particular emphasis on the analysis of KTs determinants and collaborative networks. Different studies have identified how inherent properties of the actors involved in innovation systems, as well as contextual factors, influence knowledge diffusion. In addition, KT consequences have also been frequently analysed, with a particular focus on the variables of innovation propensity and business performance, concluding that effective KT through collaborative networks generates potential innovation capacity.

The study of the collaboration network's structure has probably been the central axis of this paper' findings. First, the literature has confirmed that the centrality position of a given agent in a collaboration ecosystem, whether it be a company or a business unit, represents an essential factor for achieving efficient and effective KT flows. Second, the absorption and integration of external knowledge depends, to a large extent, on the collaboration network structure in which they are located. In other words, a more central strategic position allows the generation of collaborative relationships and, consequently, potential avenues for KT.

Our findings have also been organised according to the types of agents that make up different KT relationships. Given their inherent characteristics, MNEs have been the organizations that have received more attention. Communication and leadership are highly relevant factors in this business modality. Other research has analysed KT between universities and industry. Universities and research centres, due to their role as knowledge generators, represent an essential agent in the innovation system. In this sense, literature has specially focused on the identification of barriers that difficult KT between knowledge generators and industry. The authors converge on one main idea: the need to create mechanisms to facilitate KT practices to address the difficulties detected. Finally, public institutions also play a vital intermediary role in the achievement of collaborative learning networks. Our review has also summarized some of the recommendations encouraging the development of KT processes and, in the long run, the creation of regional value. In this sense, incentives that stimulate knowledge flows as well as the creation of a knowledge agenda can provide a roadmap that enhance innovation ecosystems.

This paper has several implications. From a theoretical perspective, this study constitutes the first systematic review that brings together two fundamental concepts in the field of business management and innovation: KT and collaborative networks. The extensive period selected and the demanding criteria of inclusion allows us to analyse the contributions with the greatest impact and to identify the research agenda. This study allows the scientific community to know what the current state of the art is, which relationships are most and least studied and where the focus should be placed in the future.

Regarding managerial implications, there is a high agreement on the benefits that the creation and dissemination of knowledge brings to first, innovative behaviour and second, economic performance. Practitioners should be aware of this. Throughout this paper, multiple arguments have been presented that defend the implementation of KT process in companies. Having a dynamic portfolio of stored business knowledge can help to detect firm weaknesses and strengths. This can allow the elaboration of strategic action plans around the construction of collaborative innovation networks. Some of the most important determinants of effective KT processes are related to social capital. In this sense, managers should implement integrated management models that take into consideration organizational aspects such as company size or location, but also intangible and human variables such as trust, leadership, culture or communication strategies.

From a macro perspective, public authorities should be aware of the innovation system landscape in their regions or countries. Making this information available to other agents in the ecosystem can enable the development of actions to improve KT processes and strengthen collaborative networks. In addition, this review has shown how the interaction between centres that generate knowledge (i.e. universities) and businesses is vital for the achievement of innovations and regional value. Public authorities must provide the necessary resources and flexible mechanisms for knowledge commercialization. Only in this way, strong and stable collaborative KT networks can be created. Finally, it has been evidenced that the creation of a collaborative culture of trust is fundamental. Public authorities can contribute to attract external agents by giving visibility to the knowledge created in a given region or sector. As a consequence, providing an innovative and transparent image can promote collaboration in KT among agents as well as attract external agents and also strengthen the culture of collaborative trust.

4.1. Limitations and future research agenda

This paper is not without limitations. An important proportion of the research analysed are case studies focusing on a single company. This research has been considered in our systematic review, but its generalization should be treated with caution. This, in turn, may constitute a future line of research. A meta-analysis that selects the quantitative articles that investigates this phenomenon may provide interesting results that complements ours. Due to the complexity of knowledge measurement, many of the selected papers could not empirically establish causal relationships. Furthermore, knowledge has been measured through different variables, i.e., patents, collaboration contracts, training courses, strategic alliances or spin-offs among others, which makes conclusions difficult to compare.

In any case, this systematic review has revealed how the study of KT and collaborative networks is a promising research field. The implications that derive from our review suggest that there are significant research gaps that may be subject of attention in the future. Table 13 synthetizes some of these future research paths.

From a conceptual perspective, current research has not empirically defined knowledge and, consequently, has not modelled KT. This is the main reason that makes generalisation and comparison of findings difficult. This constitutes a necessary but very complex research line. The intangibility of knowledge as a resource is also a challenge to be addressed and not an impediment of continuing researching in this trend. Future work may try to find out how to develop knowledge measurement scales to estimate KT indicators.

We have evidenced how the micro-perspective is the most commonly approach to analyse KT processes and collaborative networks. Although this micro approach is of undoubted interest, we understand that the availability of macro analysis has huge potential in terms of policy implications. The identification of causal relationships in a globalised knowledge-based economy is vital to improve national competitiveness and innovation indexes. As the current Covid-19 pandemic is showing us, international collaboration is fundamental to exploit externalities and synergies with high strategic value.

Our review has also detected that the literature has paid limited attention to some business configurations such as family firms, franchises or join ventures. Our findings are not necessarily exchangeable to these types of businesses, given their inherent characteristics. However, according to their frequency in the industrial sector, this could constitute a promising research niche.

All the papers reviewed in this study deal with the analysis of KT from the point of view of its advantages and benefits assuming that it is efficient. Nevertheless, this KT efficiency cannot be guaranteed. Taking into consideration possible inefficiencies in KT may derive in conclusions of interest regarding the consequences of the lack of collaboration. Widening the perspective may probably generate a greater awareness for those responsible for knowledge management and business innovation. We believe that these may constitute future lines of research of interest to all the groups involved. Finally, the generation of efficient innovation and knowledge systems represent the main interests to organisations and society. The development and implementation of integrated knowledge systems can (1) boost business competitiveness, (2) generate more employment, (3) improve social welfare, and (4) adapt regulatory frameworks to create strategic synergies.

In this sense, digital transformation can change the future dynamics of KT. The creation of digital systems that allow the integration of large volumes of data, as well as the implementation of mechanisms that manage internal knowledge, represents a promising field of research. It is important to efficiently manage learning processes, but without an adequate security and protection system, the availability of valuable knowledge sources does not guarantee the achievement of competitive advantages. Therefore, analysing the determinants, effects and consequences of the implementation of automatic KT process safety systems may be another enriching line of research in future studies.

Table 13. Future research avenues for KT and networks

Concept	Empirical knowledge definition	• Measurement of knowledge to ensure comparability of results between studies.
	KT modelling	• Alternatives to model KT. • Is there a way to capture knowledge exchange flows?
	Scale development	• Can the development of a KT measurement scale allow modelling of these flows? • Items that should contain.
Macro perspective	Identification of relationships in R&D networks	• Regions that should be consider creating formal and informal networks. • Areas of knowledge or industrial sectors to be consider.
	Current barriers and solutions	• Barriers that can be identified and how we can avoid them.
	Cultural variables identification	• Cultural variables that determine the achievement of efficient KT networks between regions.
	University-business-public institutions collaboration	• Specific protocols to encourage collaboration between actors. • Identification of other actors in regional innovation systems. • Action plans that allow to strengthen and maintain relationships.
Business modalities	Family firms Franchises Join Ventures	• Study of KT flows for these types of companies. • Importance of belonging to a collaborative learning network. • Effects on economic performance and innovation.
Inefficient KT	Consequences	• Consequences of poor management creation and KT.
	Agents to be avoided	• Agents that should not be considered in the creation of a collaborative KT network. • In what cases?
	Solutions and action protocols	• Alternatives to solve inefficient KT practices. • Design of standardized protocols.
Digital transformation	Digital systems to manage KT	• Digital systems to allow managing knowledge storage and record internal and external knowledge flows. • Specific cases in which its implementation is especially interesting and advantages and disadvantages. • Items that should be considered.
	Security systems	• Effects of incorporating knowledge protection systems in a company. • Effect's variation according to the context. • Implementation of this systems and its effect to obtain sustainable competitive advantages.
	Intelligent algorithms	• Implementation of intelligent digital systems that predict potential collaborative synergies. • Improvement of KT efficiency in performance and innovative capacity.

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Chapter 3

Exploring knowledge transfer ecosystems

Study 3

The European research landscape under the Horizon 2020 Lenses

1. Introduction

The role of collaboration and networking in innovation decision processes has long been debated in academic literature (Bogers et al., 2017; Simonin, 1999). Within this literature special focus has been placed on the need for networking between research centers, industry, and public institutions (Farinha et al., 2016; Li et al., 2018), which gives rise to the well-known Triple Helix (TH) model (Etzkowitz & Leydesdorff, 1995). While these collaborations are fundamental for any firm, they are critical in the particular case of small and medium-sized enterprises (SMEs) (Dhanaraj & Parkhe, 2006) who often lack the resources needed to independently undertake R&D actions (Li et al., 2018; Nordman & Tolstoy, 2016).

Recent studies have encouraged specific analysis of business networks with the purpose of examining complex contexts (Latorre et al., 2017; Tsai, 2001). Surprisingly, there is little transnational research to date that visualizes the existing collaborations that drive innovation in SMEs based on the agents of the TH model. With this argument in mind, our research question tries to enhance the understanding of the complex relationships that are developed in the European ecosystem. In particular, we are interested in questions such as how research on innovation in SMEs is channeled through networks and which European countries lead innovation projects in SMEs.

Given this research question, this paper has two objectives: (1) to evaluate the research landscape in Europe that promotes innovation in SMEs through analysis of Horizon 2020 strategy funding, and (2) to explore the position of each of the agents making up the TH model in their role as active subjects in research into innovation in

SMEs. To achieve this objective, we adopt network analysis to visualize the European landscape in terms of research on innovation in SMEs. To do so, we construct a database that is extracted from the European Horizon 2020 strategy (H2020). We consider all funded research projects falling under the class Innovation in SMEs. This search process resulted in 1,055 projects that were funded between 2014 and 2019, amounting to €444,557,465 distributed between 971 private firms (€377,869,420), 399 public institutions (€32,023,509) and 213 BSCs (€37,664,536).

Three types of complex networks will be developed and analyzed: through the first one, we will provide a panoramic scenario of all of the collaborative connections between European countries; the second will enable us to identify collaborative connections that classify agents according to the TH model in an aggregate way; finally, a network-based analysis approach is carried out to better visualize the collaborative connections between European agents of the TH model on an individualized basis.

This work constitutes a first step to provide a reference framework to visualize the collaborative networks in Europe that drive innovation in SMEs using the TH model as a tool. Furthermore, the analysis of centrality that underlines network analysis will allow us to identify the importance of each agent in the network and their proximity to one another. Consequently, we will first identify the degree of connectivity between European countries. Our main conclusion is that the location in the network does not have a linear relation with the funding received. Second, although most of those participating in innovation activities in SMEs are private sector companies, the most relevant drivers in the European network are BSCs. Therefore, this exploratory study contributes to the understanding of the structure and configuration of the European network of innovation in SMEs.

The rest of the paper is organized as follows: Section 2 presents a review of the academic literature. Section 3 describes the method that we adopted to carry out this research. In this section, we provide information about the data collection and the measures used in the network study. Section 4 presents the results of the empirical analysis. Finally, Section 5 discusses and concludes the paper.

2. Theoretical background

The relevance of knowledge transfer has been object of a deep discussion in recent decades (Cunningham & O'Reilly, 2018; Easterby-Smith et al., 2008; Inkpen & Tsang, 2005; Simonin, 1999). Specifically, the term refers to the process through which one business unit, group, department, or division is affected by the experience of another (Argote & Ingram, 2000; Darroch, 2005; Link & Sarala, 2019). Although this process can occur within a particular firm, there is an increasing amount of literature showing how knowledge from external sources can bring distinctive value to a company (Inkpen & Tsang, 2005) and generate competitive advantages (Easterby-Smith et al., 2008; Pérez-Nordtvedt et al., 2008; Szulanski, 1996). Scholars have argued that knowledge transfer may have positive effects both for the broadcasting and the receiving company (Argote et al., 1990; Ingram & Baum, 2002). New knowledge, especially when it is external to the firm, can be an important stimulus for change and for organizational and social improvement (Baglieri et al., 2018; Inkpen & Tsang, 2005), thus becoming an engine of economic change (Coccia, 2019; Kotabe et al., 2003; Nepelski & Piroli, 2018).

Among the drivers of knowledge transfer, the relationships established between three major social actors, namely science centers, industry, and public institutions have received increasing attention in the literature (Farinha et al., 2016) due to their contribution to societal progress and growth. The main concept that emerges from this debate is the TH model, which describes the importance of links between the above actors. These networked relationships constitute a key element in the knowledge-based economy (Etzkowitz & Leydesdorff, 1995). The TH model leads to a better understanding of a complex process that requires the involvement of numerous agents.

In the specific case of universities as science centers, their mission has recently evolved to include the increasing demand to take the needs of society more directly into account. Universities are often asked how they contribute to economic growth and entrepreneurial activity in addition to their traditional research through teaching and publication (Baglieri et al., 2018). The concept of entrepreneurial universities arises in different academic forums (Guerrero et al., 2016; Ranga et al., 2003) and is linked to the new role that they have adopted (Gunasekara, 2006; Hervas-Oliver et al., 2011). Ranga et al. (2008) argue that the presence of an entrepreneurial university offers significant competitive advantages to the region where they are established and paves the way for the creation and consolidation of knowledge regions. Research technology organizations (defined as organizations whose main business is R&D to enhance the innovative performance of their customers) constitute the second pillar of science centers. They have also reoriented their activity to strengthen their networks with private companies and the literature suggests that they should adopt a leading role in R&D collaboration (Albors-Garrigos et al., 2014).

The two types of institutions share similar objectives, and thus, closer relationships should be created between research technology organizations and universities. We integrate them under the label of BSCs. Huang et al. (2010) suggest that firms that collaborate with universities and research institutions are more likely to be R&D performers, while firms that source information from suppliers and competitors have a higher probability of innovating through non-R&D activities. Farinha et al. (2016) point out that networks generated between academia and industry enable a strong contribution to improving regional competitiveness through the development of new projects and new market technologies. As a consequence, we consider that the new enhanced mission of BSCs will have a relevant position in the ecosystem of a region through the promotion of synergies between the agents of the TH model.

The relationship between firm innovation and collaborative networks has been analyzed in the literature (Dhanaraj & Parkhe, 2006; Swan et al., 1999). Network members are exposed to the acquisition and absorption of different, potentially valuable sets of knowledge. Therefore, knowledge transfer, as an antecedent of firm innovation, arises as a consequence of the interaction and spillovers that take place between different organizations (Etzkowitz & Leydesdorff, 1995; Farinha et al., 2016). According to Inkpen and Tsang (2005), there are two mechanisms that operate at this level: (1) a network that can facilitate learning through knowledge transfer from one firm to another, and (2) a network that can become the locus of new knowledge creation. So there is evidence that a company significantly improves its innovative capabilities by taking advantage of others' skills through knowledge transfer.

Through the analysis of networks it is possible to model the relationships or interactions between a set of social entities, such as people, groups, or organizations. Therefore, the analysis of the structure of networks aims to understand the behavior of the systems that are generated. Thanks to this type of analysis, the main actors in the network can be identified. Complementarily, centrality indicators are widely researched in knowledge areas such as physics, computer science, and business. Their contributions to science are demonstrated in many papers published in high impact journals (Barrie et al., 2019; Huggings et al., 2019; Latorre et al., 2017). Actors with a "more central position" (greater centrality) have easier and faster access to other actors in the network (useful for accessing resources such as information) and a greater ability to exercise control over the flow between them. From a holistic perspective, this type of method makes it possible to analyze complex ecosystems composed of numerous subjects, visualize them, and identify the links between them. Furthermore, if centrality metrics are analyzed, all the above information is complemented with data on the positions, relevance, proximity, and importance of each individual in complex structures.

Network analysis allows, among other things, the outlining of implications and recommendations for management. It enables the identification of weaknesses and strengths of the ecosystems, as it is able to draw appropriate lines of action. In addition, this type of study allows us to know contexts that otherwise would not be possible given the multitude of interacting actors. On the other hand, the study of complex networks allows us to identify areas of high interest for collaboration, competitors, or example agents, among other aspects. In other words, special attention should be paid to the centrality and cohesion of networks that form complex ecosystems, because these indicators provide valuable information on expected future results. For example, Nordman and Melén (2008) and Xu et al. (2019) observe that networks can provide access to extended resource bases and therefore serve as platforms for business development in relationships with foreign markets. However, a successful transfer phenomenon that helps to achieve greater business innovation is complicated, because different subjects are interacting at the same time in a territory that is influenced by external features (Coccia, 2016; Rammer, 2019; Szulanski, 1996) responding to technologically and economically complex environments (Fernández-Sastre & Montalvo-Quizhpi, 2019; Teece, 2010).

Consequently, there are some studies that analyze the networks into which organizations are integrated to explain firm behavior (Latorre et al., 2017; Tsai, 2001). It has been argued that the network occupied by actors, defined by the nature of their relationships, interactions, and linkages, can be at least as important as the geographic space in which the actors are located and interact (Huggins et al., 2012). Moreover, firms with greater networking capabilities are more likely to benefit from these links. This implies that there is a significant "flow" of knowledge from the science-base to "end-user" firms via private sector consultancies, research organizations, or universities (Barge-Gil et al., 2011; Tether & Tajar, 2008). The success of inter-organizational relationships relies on having in-depth knowledge of their characteristics. For this reason, analyses that do not consider the interactions between different agents in a given network are incomplete and may derive misleading conclusions regarding the knowledge transfer process. A better understanding of the complex networks that are established between the different actors can be considered as a precursor to knowledge transfer. It is true that our research is limited to the first phase of this process, but it is a necessary condition for improving our understanding of the innovation process as a whole.

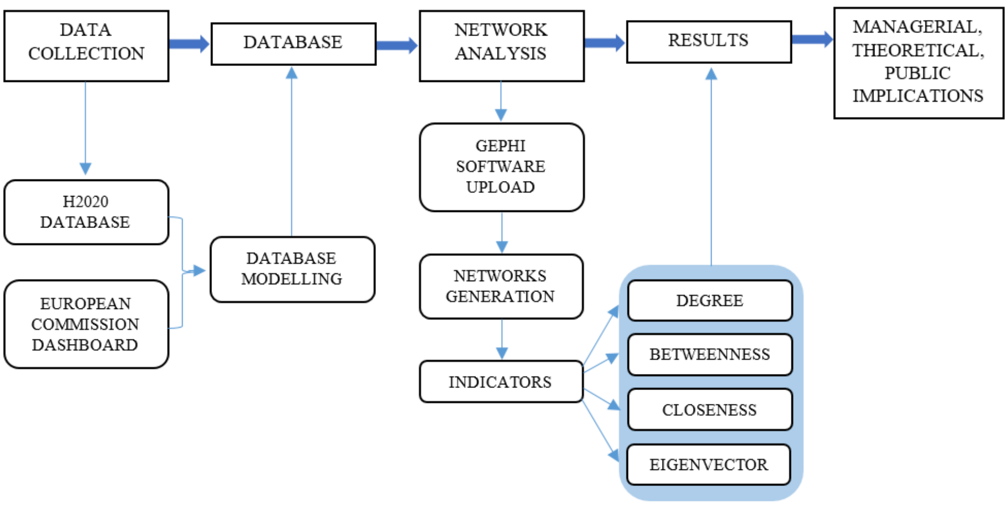
From the above arguments, we could conclude that network-based analysis has become increasingly important. Nevertheless, the results of previous research should be analyzed with care, because most of the studies are performed in technologically intensive sectors (Lamine et al., 2018) and in sectors where there is strong competition (Huenteler et al., 2016). These are sectors where large companies usually operate, the struggle for survival is evident, and having resources allocated to R&D is crucial (Cano-Kollmann et al., 2016; Gupta & Govindarajan, 2000). However, SMEs do not have the same capacity to carry out activities such as research and innovation; thus, networks are particularly important for them (Brunswicker & Vanhaverbeke, 2015). They often lack tangible resources and are therefore heavily dependent on intangible resources that are accessed outside their boundaries. Since SMEs are highly restricted in developing new knowledge on their own, complementing their own technology resources with external knowledge widens their opportunities to successfully transfer R&D results into products and processes. External R&D allows SMEs to limit their own risk, have a better control of costs or R&D, and a specialization in those technology competences for which they have the best resources (Rammer, 2009). These arguments suggest that connectivity in network environments should be considered a prerequisite for innovation, because it provides knowledge and access to resources that would otherwise not be available to individual companies (Nordman and Tolstoy, 2016), which is especially valuable for SMEs.

For example, Zeng et al. (2010) found a significant positive relationship between networks and innovation performance in their study of 137 Chinese manufacturing SMEs. Studies have also revealed that SMEs can effectively overcome size problems through access to network resources by creating, transferring, and combining resources, enabling them to discover opportunities without the need of costly research (Crick & Spence, 2005; Nordman & Melén, 2008). Similarly, de Jong and Vermeulen (2006) argue that small firms can gain competitive advantages by cultivating specific business relationships as a means of developing new knowledge, which, in turn, can lead to new innovation outcomes. Hervas-Oliver et al. (2011) conclude that R&D innovators accounted for the majority of the external resources of knowledge, and the non-R&D innovators, usually SMEs, show very low percentages of external cooperation, although they are much more active than the non-innovative firms. Li et al. (2018) analyze a sample of US SMEs and provide evidence of the importance of the local dimension of the TH interactions in transferring knowledge among innovation actors who share a nearby location. Barge-Gil (2010) found that smaller, less R&D-intensive collaborating firms are more frequent cooperation-based innovators, while large, R&D intensive firms are usually peripheral co-operators.

3. Methodology

In order to clarify the study design process, Figure 23 shows the different stages that have been carried out. Particularly, three major steps: data collection, construction of a large database and finally, generation and analysis of complex networks and indicators of centrality. Subsequently, the results are obtained and interpreted, as well as the implications and conclusions of the study are formulated.

Figure 23. Study design process



3.1. Data collection

The data collection has been carried out based on the information provided by the European Commission's website in its section on the H2020 strategy, which is the EU's largest research and innovation program to date, with funding of almost 80 billion euros over seven years (2014 to 2020). In addition to funding the development of science and technology, one of the main objectives of the H2020 program is to foster international collaboration between science organizations and private companies, both large and small. The main motivation for this strategy is that innovation is often the result of the interaction and cooperative efforts of different organizations dedicated to the achievement of a common goal. To participate in the programs, countries must belong to the EU or to the list of associated countries. In our analysis, to keep the focus on a limited geographical space—we considered all those research projects and collaborations between European countries, and we did not consider collaborations outside Europe.

The H2020 strategy is based on three main pillars: excellent science, industrial leadership, and social challenges. These pillars are structured around 35 categories that include leading research topics. In particular, we considered all funded research projects that fall under the subcategory defined as innovation in SMEs, which belongs to the second pillar (industrial leadership). This search process resulted in 1,055 funded projects between 2014 and 2019.

The total funding for the category of innovation in SMEs amounts to 444,557,465 euros. The average grant per project is 424,225 euros, and the average grant per individual participant is 249,474 euros. Given that we did not consider collaborations with countries outside Europe, the total amount considered in our study amounts to 413,423,526 euros, and the average grant per participating country is 10,600,603 euros. The database includes a total of 1,583 individual participating entities and 39 European countries. Of the total number of research projects that promote innovation in SMEs, 519 collaborative links are detected between the participating institutions.

Table 14 summarizes the data per country. As can be seen in Table 1, more than half of the amount financed by H2020 is concentrated in five countries—that is, Spain, France, Germany, Italy, and the Netherlands—, while 47% of the remaining funding is distributed among 34 countries. In addition, the last column relates the resources obtained by each country and its GDP. A higher value of this ratio would indicate that the country participates in H2020 more than expected according to its macroeconomic indicators, and vice versa. Among the biggest countries, Spain obtains twice as many resources as it would expect according to its economic weight, while Germany and, above all, United Kingdom, are underrepresented in H2020. Among the small and medium economies, the share of the Nordic countries, Estonia, Serbia and Armenia is much greater than expected.

Table 14. Participating European countries and grants financed by the H2020 strategy (2014–2019)

Country	Grant (euro)	Grant (%)	GDP (%)	Grant / GDP	Country	Grant (euro)	Grant (%)	GDP (%)	Grant / GDP
Spain	56,748,444	13.7	6.77	2.02	Serbia	2,334,513	0.6	0.24	2.48
France	52,065,714	12.6	13.26	0.95	Belgium	1,799,941	0.5	2.59	0.19
Germany	43,633,079	10.6	18.84	0.56	Croatia	1,604,770	0.4	0.29	1.38
Italy	34,832,328	8.4	9.95	0.84	Romania	1,395,996	0.4	1.14	0.35
Netherlands	30,615,484	7.4	4.36	1.70	Turkey	1,223,427	0.3	3.68	0.08
Sweden	27,269,178	6.6	2.66	2.49	Czechia	1,100,568	0.3	1.17	0.26
Norway	22,393,585	5.4	2.07	2.60	Armenia	752,800	0.2	0.06	3.37
Denmark	21,185,566	5.1	1.70	3.00	Slovenia	606,009	0.2	0.26	0.78
Finland	19,650,288	4.8	1.32	3.63	Cyprus	527,273	0.1	0.12	0.84
United Kingdom	17,788,961	4.3	13.63	0.32	Lithuania	513,594	0.1	0.26	0.39
Austria	14,963,226	3.6	2.17	1.66	Slovakia	504,765	0.1	0.51	0.20
Ireland	12,460,878	3.0	1.83	1.64	Bulgaria	436,804	0.1	0.32	0.32
Poland	10,844,936	2.6	2.80	0.93	Latvia	357,053	0.1	0.16	0.61
Switzerland	9,386,214	2.3	3.37	0.68	Malta	143,338	0.0	0.07	0.00
Portugal	6,486,982	1.6	1.15	1.39	Ukraine	100,000	0.0	0.62	0.00
Iceland	5,774,105	1.4	0.12	11.30	Montenegro	43,994	0.0	0.03	0.00
Greece	4,049,466	1.0	1.04	0.96	North Macedonia	23,713	0.0	0.06	0.00
Estonia	3,564,756	0.9	0.15	6.13	Moldova	14,225	0.0	0.05	0.00
Luxembourg	3,312,144	0.8	0.34	2.36	Bosnia Herzegovina	5,689	0.0	0.09	0.00
Hungary	2,909,721	0.7	0.75	0.93					

The variables that are analyzed in our study can be classified into four main groups: those relating to subsidy (by country, organization, project, and type of agent), geographical location (at country level), the number of collaborations (between countries) and the type of agent (public institutions, industry, or science centers). Several indicators of centrality will be used in our empirical study, which are very useful in complex networking techniques. These measures are developed in the following section.

3.2. Network analysis and centrality measurements

As said in previous sections, knowledge transfer, as an antecedent of firm innovation, arises as a consequence of the interaction and spillovers that take place between different organizations. Increasingly, this process is viewed as a systemic undertaking, i.e., firms no longer innovate in isolation but through a complex set of interactions with external actors. Therefore, external knowledge networks are potentially an important aspect of the innovation process. It is through these pipelines that firms procure knowledge that they do not, or cannot, generate internally based on their own capabilities. In other words, knowledge transfer takes place trough knowledge networks and spill overs between firms (and other agents that interact in the innovation ecosystem).

With this in mind, this section shows the relevance of the analysis of complex networks, as well as the theoretical description of the centrality measures used in the paper. First, we explain what a network is and what its advantages are. Next, we describe the measures used to analyze the networks.

Network analysis is an approach that uses different measures to describe and link the relationship that exist between entities. The advantages of using network analysis in our research are twofold: (1) it allows a better understanding of how European research on innovation in SMEs works; and (2) it can be used as a resource allowing individual entities to study their own relationships and make comparisons with other agents, providing value information that can be useful in the adoption of future decisions.

In the first place, we define the types of networks that we examine in this work. Let G = (V, E); be a graph in which V represents the set of institutions or entities (we use the term nodes, institution and entities with the same meaning) participating in H2020 in our field and E represents the set of links or collaborations between them. Let (vi, vj) ∈ E, with vi, vj ∈ V, be an edge in G that represents any kind of relationship between institutions vi and vj.

In this document we only focus on directed graphs, since we assume that the relations are directional, that is, if there is (vi, vj) ∈ E it does not imply that (vj, vi) ∈ E does not necessarily exist. Therefore, the graph G generated by the network is directed. This approach allows us to analyze this type of network as a tool to interpret and improve the performance of network entities, which has direct implications from a management perspective.

Centrality metrics are necessary to shed light on the importance of an entity's position in the network. These allow us to understand behaviors and properties in a network. As said previously, actors with a greater centrality have easier and faster access to other actors in the network and a greater ability to exercise control over the flow between them. Some centrality metrics are explained below.

Degree centrality (Freeman, 1977), identifies the number of links a node has and shows how well an institution is connected in terms of direct links. Although it perfectly denotes the degree of connection of an institution, it does not reflect the position it occupies in relation to the network. Its theoretical representation is:

$$DC^{v_i} = \frac{d(v_i)}{|V| - 1}$$

where d (vi) denotes the degree of centrality of the node vi in the network.

Closeness centrality (Beauchamp, 1965), denotes how close a given node is to any other node in the network. This could be interpreted as an agent's ability to connect with other agents. It emphasizes the distance of one actor from others in the network by focusing on the geodetic distance of each actor from all others. Mathematically, it is represented as follows:

$$CC^{v_i} = \frac{|V| - 1}{\sum_{v_i \neq v_j} sp(v_i, v_i)}$$

where sp (vi, vi) is the number of connections on the shortest path between the vi and vj node.

Betweenness centrality (Freeman, 1977), measures the frequency with which a given node appears on the shortest path between any two nodes in the network. This metric is used to measure the relevance of an agent in the network and to explore the influence these agents may have on a possible mediation to initiate a new relationship. Let np (vj, vk) be the number of routes between vj ∈ V and vk ∈ V. Then, we obtain the centrality of the node vi in terms of connecting vj and vk as a ratio. Formally:

$$BC^{v_i} = \sum_{v_j \neq v_k \neq v_i} \frac{\frac{np_{v_i}(v_j, v_k)}{np(v_j, v_k)}}{\frac{1}{2}(|V| - 1)(|V| - 2)}$$

Eigenvector centrality (Bonacich, 1987), represents the importance of a node in the network. It is based on the fact that the centrality of a particular node depends on how central its neighbors are. It is a more elaborate version of the degree centrality by assuming that not all connections are of equal importance. Let EC (G) be the centrality of a vector associated with a network G; the crux is that the centrality of a node is proportional to the sum of the centrality of its neighbors. Its representation is:

$$\lambda \cdot EC^{v_i}(G) = \sum_{v_j} g_{ij} EC^{v_j}(G)$$

in which gij takes the value 1 if (vi, vj) ∈ E and 0 otherwise and k is a proportional factor.

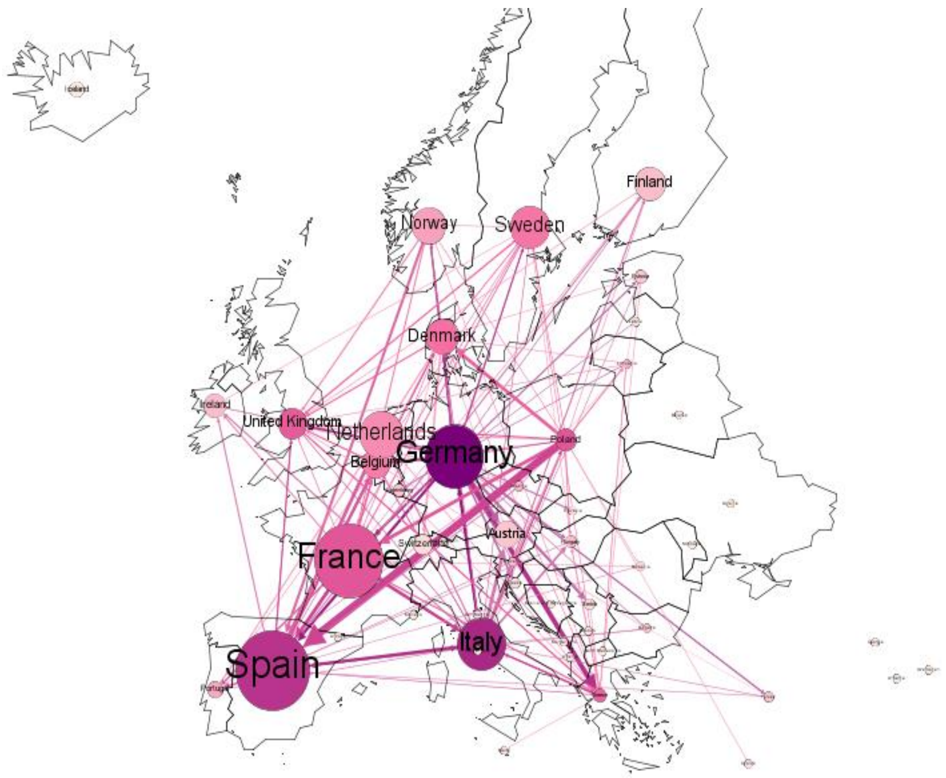
4. Results

Three different scenarios have been analyzed. The first scenario gives visibility to the European network by participating countries. The second scenario shows the knowledge transfer between the three main agents of the TH model. Finally, in the third scenario the entire network is analyzed by disaggregating the data by participating entities in the whole of Europe. We consider these scenarios because, on the one hand, they provide a European descriptive panorama in which we visualize the collaborative capacity in innovation of SMEs by countries; while on the other hand, the individual analysis allows us to identify the most important agents in a complex context in which the capacity for connection is fundamental.

Figure 24 presents a graphic representation of the network generated on the European stage. The size of the nodes represents the amount of finance granted by the H2020 strategy to projects belonging to the field Innovation in SMEs (the greater the size of the nodes, the higher the amount of funding grants). The color of the nodes is related to the degree centrality coefficient, which allows us to perceive the degree of connection of institutions: nodes with higher centrality are darker. The arrow that measures the links is the sum of the number of collaborations between the two countries in the total of the financed projects, which are colored according to the average of the connected relationship. It is deduced from the network that the countries that receive the most funds to promote innovation in SMEs are Spain, France, and Germany.

The degree of centrality of each of the countries differs with respect to the financial amount perceived. In this case, the node with the highest degree of centrality is Germany as the country that collaborates most with the other countries in industrial innovation projects, followed by Italy and Spain. Another dimension that this representation allows us to analyze are the collaborative links that exist in Europe. In this sense, the countries that have developed the greatest number of collaborations are Poland and Spain. In addition, it is possible to contemplate that the mesh has a greater density in the European center than in the peripheries. As the countries move away from the old continent, the network seems to become more fragile.

Figure 24. Network of the EU countries who participate in *Innovation in SMEs* (2014-2019)



Note: Node size is related to the perceived amount. Node color is associated with the degree centrality coefficient. The thickness of the link represents the sum of the number of collaborations. The color of the link represents the average of the connected relationship.

The results of the centrality metrics are shown in Table 15, which provides some interesting findings. In this table, we have included all these European countries that have participated on at least one occasion in the program. According to the degree centrality, Germany, followed by Italy and Spain, occupy the most relevant positions. This means that they are more frequently related to the other countries. Focusing on the closeness centrality, eigenvector centrality and betweenness centrality, the results lead us to similar conclusions. Germany stands out in each of the measures. Other nodes with high values of our key indicators are Italy, Spain, the United Kingdom, Poland, and Denmark. This suggest that these countries have the shortest average distance in comparison with the rest of the network nodes (closeness centrality). It is also more likely that they are present in the way of connection between two nodes (betweenness centrality).

This metric lets us interpret how good the countries are in terms of being intermediaries in research collaborations. As explained in the previous section, the eigenvector centrality represents the importance of a node in a network. In this case, Germany, Spain, Italy, Poland, the United Kingdom, France, and Denmark represent the countries with the greatest distinction in the network. This general picture reveals several interesting aspects. First, we can conclude that receiving a lot of funding from H2020 is not as important as having a good position in the network in terms of centrality. Second, this is a complex and apparently well-cohesive network, so its possible fragmentation seems complicated. This fact at least applies to the center of the continent, where most of the interconnections are concentrated. Consequently, this high cohesive density will allow the flow of innovative knowledge to work efficiently between countries where network fragmentation seems difficult.

Table 15 Results obtained using centrality measurements in EU

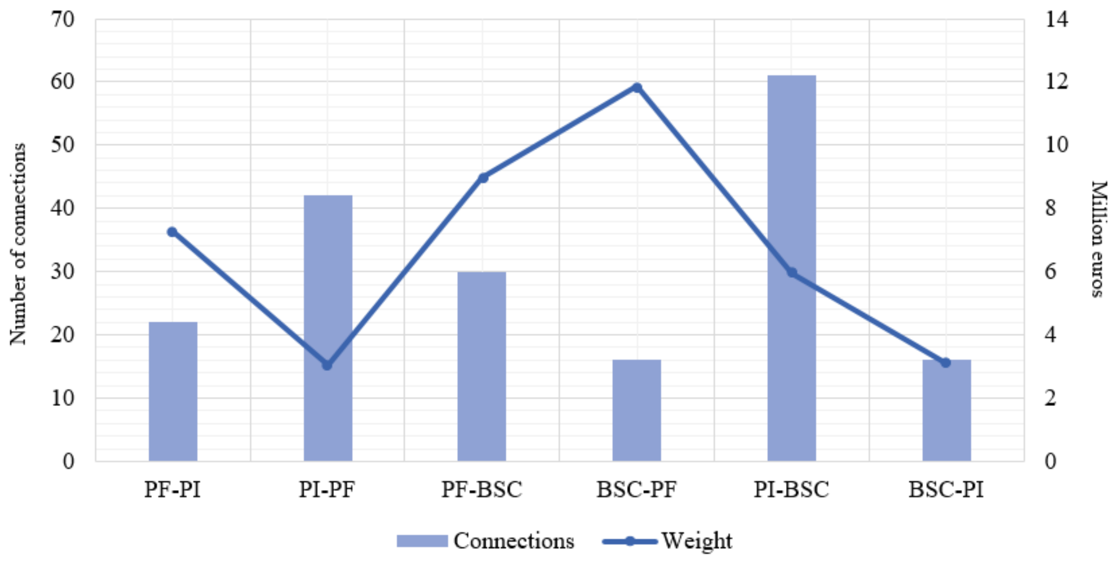
Id	Betweenness centrality	Closeness centrality	Degree centrality	Eigenvector centrality
Austria	3	0.516	5	0.242
Belgium	0	0.571	15	0.602
Bosnia and Herzegovina	0	0.368	2	0.046
Bulgaria	0	0.508	5	0.298
Croatia	0	0.471	2	0.154
Cyprus	0	0.410	1	0.067
Czechia	0	0.508	7	0.305
Denmark	6	0.653	17	0.707
Estonia	0	0.516	5	0.299
Finland	0	0.525	6	0.422
France	2	0.627	21	0.750
Germany	26	0.842	36	1.000
Greece	8	0.627	19	0.687
Hungary	0	0.533	6	0.408
Ireland	0	0.516	6	0.411
Italy	8	0.727	29	0.873
Latvia	0	0.464	1	0.082
Lithuania	1	0.552	8	0.380
Luxembourg	0	0.508	5	0.262
Malta	0	0.390	1	0.056
Netherlands	3	0.582	13	0.551
Norway	0	0.552	10	0.535
Poland	9	0.681	21	0.821
Portugal	0	0.552	9	0.508
Romania	0	0.451	3	0.202
Serbia	0	0.478	2	0.139
Slovakia	0	0.464	1	0.082
Slovenia	3	0.525	6	0.300
Spain	7	0.727	27	0.911
Sweden	1	0.604	16	0.695
Switzerland	0	0.416	2	0.103
Turkey	0	0.500	5	0.253
Ukraine	0	0	0	0
United Kingdom	3	0.653	20	0.811

Note: Betweenness and degree centrality goes from 0 to infinite. Closeness and eigenvector centrality goes from 0 to 1.

To build the second scenario, which consists of the generation of an aggregated complex network that identifies the connections between the three agents of the TH model, it was necessary to classify each entity according to their industrial activities, particularly by individually consulting its corporate information. The criterion that we followed was to consider as public institutions those entities that belonged to the government and those whose financing from public sources exceeds 50%. Therefore, all educational institutions and science centers were included in the BSC sector due to the new entrepreneurial role that they have assumed. Finally, to differentiate private sector companies and science centers into different categories, the activities, competencies, products, and services offered by each of them were consulted. In the case of the science centers, their main activity consists of carrying out R&D tasks. In contrast, the competences covered more fields in private sector companies, such as consultancy, sale of products or employee training, among others. In particular, 971 private firms participated in research projects related to innovation in SMEs (377,869,420 euros), 399 public institutions (32,023,509 euros), and 213 BSCs (37,664,536 euros).

Figure 25 shows, through a histogram, the relationships created for the generation of the graph and the weight of these collaborations in terms of the monetary amount financed by H2020. The lack of parallelism between the number of connections and the perceived quantity is confirmed. This means that the values obtained both in number of connections and in perceived resources are not necessarily coincidental and depend on the role adopted by the different actors. For example, when private companies are project leaders and public institutions adopt a collaborating role (see the first bar in Figure 25), the number of connections is lower and the volume of resources obtained is much greater than if the role of the agents is exchanged. This fact also occurs in the pair of actors composed of private companies and BSCs.

Figure 25. Histogram with the connections and weight data represented in TH aggregated network (2014–2019)

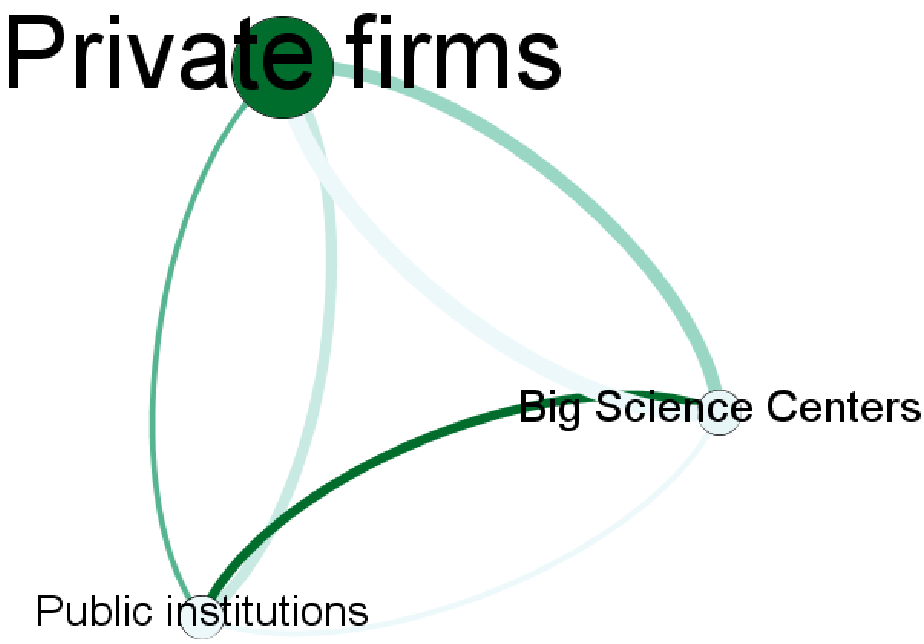


Note: Connections refers to the total number of links between agents. Weight represents the total amount assigned by the H2020 strategy to the different actors (millions). The first agent of the relations occupies a leadership role in the projects and the second agent occupies a role of collaborator or executor. Acronyms: PF = Private Firms; BSC = Big Science Centers; PI = Public Institutions.

Figure 25 complements the information provided by Figure 26 by representing the connections generated between the three agents of the model. The size of the nodes illustrates the total amount of resources granted to each of the sectors (private firms represent 84.43% of the total amount of grants, while public institutions represent 7.16% and BSCs 8.42%). The origin of the links is represented by the coordinating entities of the research projects (leading role) and the destination by the collaborating entities (executer role). The links are colored according to the number of connections between agents (the color is darker when the number of collaborations is greater).

This second aggregated ecosystem enables us to identify, in a descriptive way, some interesting aspects. In the case of the BSCs, the number of collaborations is very limited in their role as project leader. However, their role as executor is much more important, both, in their relationship with private firms and with public institutions. The opposite can be said about public institutions, who often act as project leaders but do not execute the projects. In contrast, this analysis reveals that the collaborations between BSCs as coordinators and private companies as executor are beneficiaries of a greater number of subsidies than the other relationships. In addition, the number of relationships in which private firms have the coordinating role is higher than in those in which the BSCs have the coordinating role, but the funding obtained is much lower.

Figure 26. Aggregate network of the EU participants and collaborations under the Innovation in SMEs projects according to the TH model (2014–2019).



Note: Node size and color are related to the perceived amount. The thickness of the links illustrates the grants financed. The color of the links represents the number of connections. The directions of the links refer to their role as leaders (origin) or executers (destiny).

Table 16 complements the information provided in Figure 26 by summarizing the 10 institutions that have perceived the greatest funding in each group according to the distinction made by the TH model. The five most financed institutions correspond to private sector companies (e.g., Norway Health Tech and Fundingbox Accelerator Sp Zoo standout), while the first public institution ranks 15th.

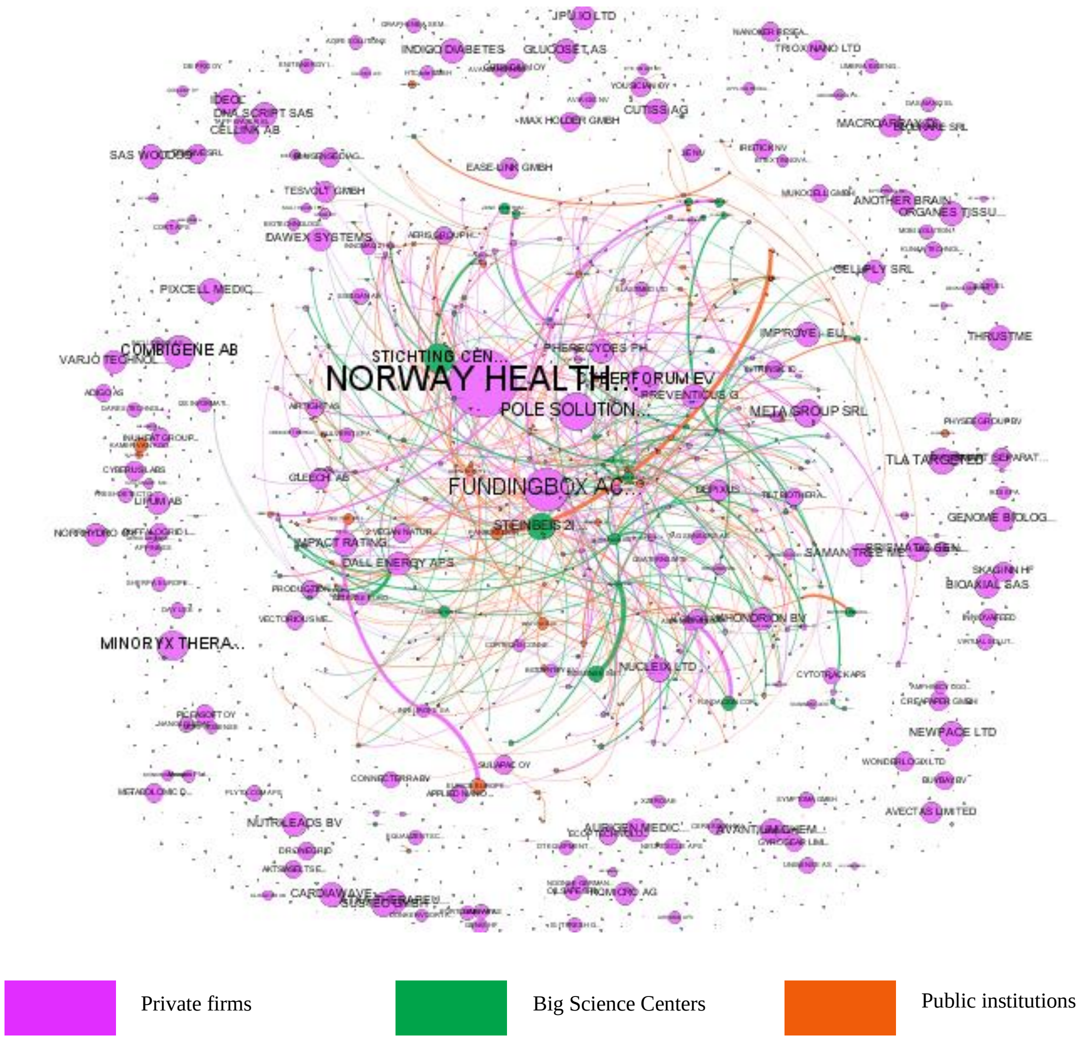
Table 16. Top 10 granted institutions according to every TH model actor (2014–2019)

Rank	Institutions	Country	Agent[a]	Grant (euros)
Group 1				
1	Norway Health Tech	Norway	PF	7,349,069
2	Fundingbox Accelerator Sp Zoo	Poland	PF	4,611,144
3	Pole Solutions Communicantes Securisees	France	PF	3,909,313
4	Combigene Ab	Sweden	PF	3,361,348
5	Cyberforum Ev	Germany	PF	3,291,419
6	Minoryx Therapeutics S.L.	Spain	PF	3,106,250
7	Meta Group Srl	Italy	PF	2,860,625
8	Tla Targeted Immunotherapies Ab	Sweden	PF	2,695,000
9	Avantium Chemicals Bv	Netherlands	PF	2,499,999
10	Bioaxial Sas	France	PF	2,499,999
Group 2				
1	Stichting Centre Of Expertise Watertechnologie	Netherlands	BSC	3,182,781
2	Steinbeis 2i Gmbh	Germany	BSC	2,830,984
3	Biosense Institute	Serbia	BSC	1,594,500
4	Fundacion Corporacion Tecnologica De Andalucia	Spain	BSC	1,371,608
5	Foundation For Research And Technology Hellas	Greece	BSC	1,077,708
6	Aerospace Valley	France	BSC	1,053,568
7	Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.	Germany	BSC	1,004,206
8	Bayern Innovativ - Bayerische Gesellschaft Fur Innovation Und Wissenstransfer Mbh	Germany	BSC	961,150
9	Fundacja Partnerstwa Technologicznego Technology Partners	Poland	BSC	768,213
10	Stichting Wageningen Research	Netherlands	BSC	692,878
Group 3				
1	Eurice European Research And Project Office Gmbh	Germany	PI	1,333,250
2	Paris Region Entreprises	France	PI	1,232,531
3	Kamer Van Koophandel	Netherlands	PI	1,182,310
4	Instituto De Fomento De La Region De Murcia	Spain	PI	1,073,516
5	Institut De La Propriete Intellectuelle Luxembourg	Luxembourg	PI	1,044,316
6	Agenzia Per La Promozione Della Ricerca Europea	Italy	PI	835,104
7	Ministerie Van Economische Zaken En Klimaat	Netherlands	PI	809,880
8	Agencia Per A La Competitivitat De La Empresa	Spain	PI	634,337
9	Agenzia Nazionale Per Le Nuove Tecnologie, L'energia E Lo Sviluppo Economico Sostenibile	Italy	PI	627,810
10	Vlaamse Gewest	Belgium	PI	581,625

Note: [a] Acronyms: PF = Private Firms; BSC = Big Science Centers; PI = Public Institutions.

Finally, with the aim of analyzing the structure of relationships in greater depth, Figure 27 and Figure 28 consider all of the individual companies that collaborate in the H2020 strategy—they depict the same network but with a different software layout. The two representations locate the most interconnected nodes in the center of the network, while the nodes of minor importance extend towards the outer region. The color of the nodes represents the group in which they are classified according to the TH model (i.e., private sector companies, public sector institutions, and BSC). In Figure 27, the node's size is determined by grant disposal. In both representations, the thickness of the links is measured through the total amount of money financed by the H2020 strategy, the direction of the connection between the coordinating entity of the project and the other collaborators, and finally the links are painted the same color as the node of origin. In Figure 28, the node's size is determined by the degree of centrality.

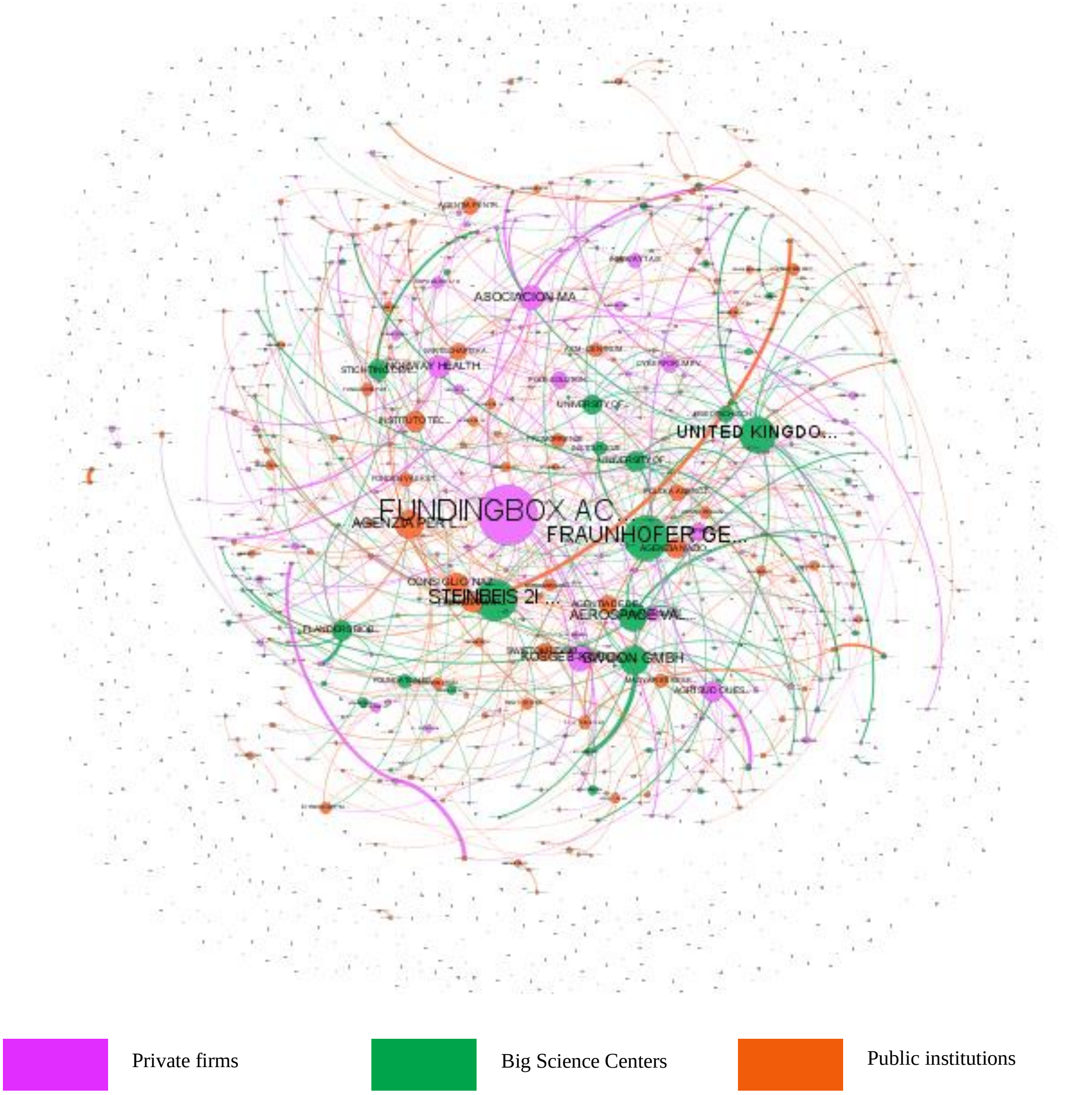
Figure 27. Network of the EU participants and collaborations under the Innovation in SMEs projects according to the TH model (total amount of grant layout) (2014–2019)



Note: The size of the node is related to the perceived amount. The color of the node refers to the TH kind of agent. The thickness of the link illustrates the grants financed. The color of the link represents the origin of the collaboration.

The comparison of the two images allows us to derive some meaningful conclusions. Although private companies obtain a great amount of resources, their connectivity is low compared with BSCs (green color). They manage many less funds but reach a high connectivity in the complex entire network. In addition, the position of private sector companies (purple color) is more moderate, in spite of their large participation in projects about innovation in SMEs and their high involvement in raising funds for their development. Finally, public institutions (orange color) do not occupy central positions in the network and have bad cohesiveness with the other participating entities. We can derive from them that the entities that have received the greatest economic funding, mainly private sector companies, do not necessarily have a good connectivity capacity with the other nodes.

Figure 28. Network of the EU participants and collaborations under the Innovation in SMEs projects according to the TH model (degree centrality layout) (2014-2019)



Note: The size of the node is related to the degree centrality. The color of the node refers to the TH kind of agent. The thickness of the link illustrates the grants financed. The color of the link represents the origin of the collaboration.

Table 17 summarizes the results extracted from the centrality analysis carried out by breaking down the entities and classifying them according to the actors of the TH model. Specifically, the top 10 values of each measure are presented. However, the total number of companies included in Table 17 is only 20 because most of the companies rank similarly in the top 10 in several indexes. Attending to the distribution of the entities with greater values with respect to the centrality indicators, we identify that 11 entities are BSCs and four are private sector companies. The institutions of the public sector do not have high significant values in relation to any of the centrality measures analyzed.

If we pay attention to the degree centrality, we see how the BSCs have values above the average; for example, Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v., Steinbeis 2i GmbH, or United Kingdom Research and Innovation, with values of 21, 19, and 17, respectively. The entity most central to this measure is a private sector company, Fundingbox Accelerator Sp. z o.o (28). These nodes, attending to the theoretical definition of the measure are the ones that a priori have a greater degree of connectivity.

However, as stated above, this measure is not enough. The measure of closeness centrality provides interesting results. Because its values are normalized [0, 1], the entities with values closer to 1 will represent those nodes that have less mean distance compared to any other in the network and, therefore, more potential to create future collaborations with other nodes. United Kingdom Research and Innovation (0.944), Bwcon GmbH (0.933), and Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v. (0.852) have greater closeness centrality and they all belong to the BSCs sector.

One of these nodes also stands out in the measure of betweenness centrality, which is Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v. Meanwhile, Steinbeis 2i GmbH, Fundingbox Accelerator Sp. z o.o, and Tillväxtverket also stand out. This reveals the importance of the agents because it shows the possibility of intervening and initiating a possible mediation in a new collaboration. Once again, the relevance of the BSCs in the network is verified. Finally, the eigenvector centrality [0, 1], shows how these three science centers that have stood out in the previous measures of centrality, are the most relevant nodes in the network, which are Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v., Steinbeis 2i GmbH and Fundingbox Accelerator Sp. z o.o.

5. Discussion and conclusions

Knowledge generation and transfer, both between and within organizations, are fundamental processes while developing R&D activities (Cunningham & O'Reilly, 2018; Easterby-Smith et al., 2008), which often derive in new products or processes through innovation. However, SMEs, due to their lack of enough tangible and intangible resources see that their efforts to individually carry out innovation are often frustrated (Brunswicker & Vanhaverbeke, 2015). Consequently, they are forced to abandon these activities, or, alternatively participate in collaborative networks to develop their R&D. However, the works reviewed in the literature do not confront this issue from a sufficiently generic and holistic perspective. Within this context, the TH model, which explicitly recognizes the relevance of the interconnections between companies, public institutions, and research centers and universities, is an appropriate tool to understand the relationships between the different agents and will allow, at a later stage, the laying of foundations to spread the innovative activities among a greater number of companies.

To evaluate the success of this interaction, we use network analysis to assess the relevance of the main actors (nodes) of the process. We introduce the concept of centrality, which is borrowed from physics and computing, and we calculate the following four types of centrality to evaluate the connectivity and importance of each agent: degree centrality, betweenness centrality, eigenvector centrality, and closeness centrality. As part of our main results, we show that there is not a direct relationship between the funds obtained in the H2020 program and the economic significance of the different countries. Neither is there a clear connection between the quantity received from H2020 and the strategic positioning in terms of connectivity, or the economic relevance of the country. In this respect, Germany, Spain, and Italy represent the countries with the best power of collaboration and connectivity in the whole network. Therefore, these countries, which show higher values of centrality, can be regarded as interesting nodes to be considered for future collaborative networks.

We have also concluded that while private sector companies globally obtain the highest amount of funds to carry out innovative activities, their relative importance is lower when we refer to knowledge transfer with other agents with the aim of creating collaborations and obtaining synergies. In this sense, BSCs do not receive as much funding from H2020 but they are much better positioned in terms of centrality in the European network. Therefore, BSCs emerge as key drivers of innovation for SMEs.

This research shows that the most cohesive parts of Europe correspond to what is known as the "old continent". This means that the highest collaborative density is established between the countries in the heart of the continent and that the network between these countries will be more difficult to break. Nevertheless, there are also countries that do not belong to this group and that have achieved excellent results in these programs: examples are Spain, Armenia, Portugal, Serbia, and Croatia. It can be argued that less centralized countries, generally of smaller size, may identify large and more cohesive countries as barriers and may often find it difficult to generate potential collaborations, with the undesired consequence that potentially valuable research projects that come from these peripheral countries may be lost. The most dangerous threat that derives from these results is associated with feelings of frustration and demotivation for firms that do not belong to this collaborative network. In addition, the high competitiveness of countries with similar characteristics (high centrality and capacity for innovation) can also be understood as a threat by the other regions. Small countries have to be able to develop action policies, identify them, and try to improve their results. Therefore, countries have the potential to identify partners and join the European innovation research network for SMEs to seek the optimal balance and symmetry of the network.

An issue that is beyond the scope of this work has to do with who should be in charge of these innovative activities. In a globalized world, it can be argued that the improvement of European social welfare is even more important than the origin of the countries that contribute to it. It should also be noted that the fact that a country or an institution does not receive funding in its first collaborations in H2020 projects should not be necessarily taken as a bad thing to the extent that the establishment of relations with other countries and institutions will make these countries take a leading position in future projects and increase the funding obtained (learning effects). Within this context, we should pay special attention to the centrality and cohesiveness of the network developed because these indicators provide valuable information about expected future results. In this sense, we understand that H2020 is a powerful tool in the strengthening of the European collaborative research network.

The results that derive from the analysis have several implications for academia, management, and the public authorities. From an academic point of view, this work allows us to visualize the global European scenario of research in innovation in SMEs, advancing a step further in the subject, and filling a gap in the literature of innovation and management. As the empirical results have shown, measuring research collaborations across networks using centrality indicators may be a fruitful and complementary alternative when modelling management situations. In addition, we have introduced the

TH model as an analytical tool, which gives our study a distinctive value that allows us to identify business opportunities among the different agents of the network. This type of detailed information could assist analysts in identifying where weaknesses in innovative ability occur and can support policy to encourage firms to move up the ladder of innovative capabilities. The results also clarify the role of relationships in innovation by highlighting the distinct differences between firms, institutions, and research centers. The latter increases the probability of performing R&D, possibly because the information provided by customers reduces market uncertainty. Although the details of innovation support policies are likely to differ across regions or countries to account for local conditions, the results of this study suggest there are consistent patterns between countries that occupy similar positions in the network.

From a decision-making perspective, managers should be aware of the positive spillovers that derive from collaboration. In this sense, universities and other science centers play a fundamental role in this process and should be considered as partners whose collaboration will be beneficial for both parties. Similarly, joint R&D projects with other companies may also strengthen the competitive position of SMEs. Studies such as the one developed in this research allow us to identify the entities that have a greater connectivity and are therefore more qualified to generate potential relationships. In addition, this study can be used as a tool that allows entities to visualize current relationships and predict future relationships with the aims of improving their effectiveness and sharing new joint knowledge. It can also demonstrate whether there is knowledge transfer and therefore can draw up strategies aligned with regional policies to improve territorial development.

Finally, from a policy perspective, this kind of analysis can be helpful in the process of resource allocation. The use of this type of tool will enable the identification of some of the strengths and weaknesses of the innovation system of a country. The information provided by the centrality indicators will be valuable in performing a detailed analysis that focuses on specific companies, industries, or countries with the aim of guiding policy decisions. Once we know which countries or which companies lead the R&D European scene in a given area, it would be easier to develop the appropriate actions that facilitate a firm's own competitiveness or to identify industries that can reach central positions in the networks in case of receiving initial support.

An issue that cannot be forgotten is the positive spill-overs of universities and research centers as drivers of innovation in Europe. As a consequence, it is important to provide them with the necessary resources to strengthen their interaction with SMEs to the extent that these networks will have positive effects on business (and, thus, society) performance. The knowledge that resides in universities and research centers is potentially a global asset, and policy makers should be responsible for establishing mechanisms to ensure the effectiveness of this knowledge transfer.

The secondary position of government institutions in the network leads us to think that there is not enough awareness of the specific characteristics and problems of SMEs. Public authorities should be conscious of the leverage role that they can play when adopting an active role in the R&D ecosystem. There are several dimensions that could be considered to achieve a more cohesive network: conflicts of interest between the parties undertaking the cooperation, lack of resources both in the private sphere and in that of research centers and universities, and bureaucratic obstacles related to the mechanisms needed to have access to the structural funds.

In addition, at a European level, this information can be helpful in the formulation of a roadmap for the continuation of H2020 that would favor the achievement of certain objectives. By way of example, the EU should decide whether it prefers to strengthen the position of the most important European consortia to enable them to compete with the main American and Asian leaders, at the cost of limiting the development of other companies, or if it chooses to opt for a more horizontal and less focused support that allows the development of a greater number of companies. Or perhaps it might be better to launch differentiated programs that provide different treatment for each of the two typologies mentioned.

To sum up, we believe that this research would be useful in several dimensions within the public arena, namely: (1) to enhance the government role as a provider of subsidies, (2) to assist in the process of creating new collaborations in the process of consolidating the existing ones, (3) to attract entities and strengthen linkages between them to enhance the stimulation of knowledge spillovers, (4) to contribute to the consolidation of trust among actors to create a culture of collaboration and confidence, and (5) to contribute to increased awareness of the role of innovation in SMEs and to promote the adoption of a more proactive attitude.

Beyond the progress that this research entails, the paper is not without limitations. Our analysis has been addressed by aggregating all funded research projects between 2014 and 2019. This provides us with a global picture of the whole innovation system during the period. However, we lack a dynamic vision of the process, insofar as we have not identified the possible existence of a time pattern. Therefore, we recommend that future research should increase the sample size with the aim of complementing this investigation with a year-by-year analysis that could identify this evolution over time. Future work could also explore the overview of a country or industry in an individual way. To the extent that there are specificities that characterize them, their individual analysis may provide richer and more detailed information. Similarly, it would be of interest to analyze networks between a given kind of agent, such as collaborations between BSCs. In this sense, the lack of more detailed, micro-level data constitutes a limitation insofar as it prevents the analysis of the complex relationships arising from these interactions. As a consequence, future research should try to combine network analysis and exhaustive firm level information (probably collected through surveys) in order to deepen these interactions.

Due to the holistic character of the study, it does not explore in depth the role of collaborator or coordinator adopted by each organization in the different research projects carried out by the agents of the TH model, and that may constitute an interesting further line of research. This issue could be taken into account using data that put a value on variables related to human resources. In addition, by focusing the design of the analysis on Europe, collaborations with countries outside the continent that may be of interest are left out. However, these projects represent a reduced number in H2020, and we consider that their inclusion would not affect the main results and conclusions obtained in this research. Finally, the methodology that we have employed does not allow to establish causal relationships between the resources allocated and the specific consequences that derive from the use of these resources. As a consequence, future work that tries to establish these causal relationships by using alternative methodologies would be welcome.

Table 17. Centrality results from the network analysis among every entity. Italics show the top 5 values in each indicator (2014–2019)

Firm	Sector[a]	Country	BC	BR	CC	CR	DC	DR	EC	ER
Aerospace Valley	BSC	France	9.213	7	0.700	14	*13*	*5*	0.285	6
Agenzia per la Promozione della Ricerca Europea	PI	Italy	6.013	9	0.824	10	13	7	*0.325*	*5*
Asociación Madrid Plataforma Aeronáutica y del Espacio	PF	Spain	0.162	65	*0.841*	*5*	11	8	0.121	19
Bwcon GmbH	BSC	Germany	2.608	25	*0.933*	*2*	13	6	0.177	13
Chambre De Commerce Et D Industriedu Luxembourg Belge Asbl	PI	Luxembourg	0.058	68	0.833	9	4	48	0.006	48
Consiglio Nazionale delle Ricerche	BSC	Italy	2.750	24	0.585	21	10	11	0.202	10
Ethniko Idryma Erevnon	PI	Greece	1.542	41	0.413	43	5	38	0.206	9
Foundation For Research And Technology Hellas	BSC	Greece	11.387	6	0.612	19	6	26	0.252	7
Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v.	BSC	Germany	*15.759*	*4*	*0.852*	*3*	*21*	*2*	*0.762*	*2*
FundingboxAccelerator Sp. z o.o	PF	Poland	*18.096*	*2*	0.740	12	*28*	*1*	*1.000*	*1*
Institut Jozef Stefan	BSC	Poland	*13.657*	*5*	0.325	47	6	25	0.136	17
Norddanmarks Eu-Kontor	PI	Denmark	0.183	64	0.834	7	5	36	0.011	42
Norway Health Tech	PF	Norway	2.516	27	0.508	24	10	9	0.165	15
S. I. Impresa (Servizi Integrati Impresa)	PF	Italy	1.357	43	*0.848*	*4*	7	23	0.057	31
Steinbeis 2i GmbH	BSC	Germany	*22.509*	*1*	0.623	18	*19*	*3*	*0.752*	*3*
Stichting Centre Of Expertise Watertechnologie	BSC	Netherlands	7.253	8	0.476	38	9	16	0.102	27
Swietokrzyskie Centrum Innowacji Itransferu Technologii Sp (Zoo)	PI	Poland	0.547	52	0.833	8	8	20	0.014	39
Tillväxtverket	BSC	Sweden	*16.238*	*3*	0.837	6	5	37	0.189	12
United Kingdom Research and Innovation	BSC	UK	4.225	16	*0.944*	*1*	*17*	*4*	*0.336*	*4*
University of Brighton	BSC	UK	5.637	10	0.581	22	9	10	0.208	8

[a] The acronyms reflected in column 2 make reference to the type of agent according to the TH model (PF = private firms; BSC = Big Science Centers; PI = public institutions).
[b] (BC = betweenness centrality; BR: betwenness rank; CC: closeness centrality; CR: closeness rank; DC: degree centrality; DR: degree rank; EC: eigenvector centrality; ER: eigenvector rank)
[c] Betweenness and degree centrality ranges between 0 to infinite.
[d] Closeness and eigenvector centrality ranges between 0 to 1.

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Chapter 4

Do collaboration structures matter in regional innovation systems?

Study 4

Do collaboration structures matter in regional innovation systems?

Evidence from European knowledge transfer dynamics

1. Introduction

One of the main current fields of research in the innovation literature is the understanding of collaboration flows. Until recently, it was accepted that innovation should be achieved simply by increasing R&D investment in GDP across the board (Hervás-Oliver et al., 2021). As a consequence, public policies were, for some time, oriented towards funding individual firm investments in R&D. But this approach has been criticised by academia, industry and policy makers alike as it does not consider the context specificities of regions where companies operate (Cooke, 1992). Innovation today is increasingly collaborative and the level of innovation is, to some extent, determined by the structure of the ecosystem. In this way, understanding this new setting for innovation is attracting scholars' attention.

Nevertheless, the study of this new setting is complex; first, because boundaries are not clearly defined anymore, generalising results about a specific context to others has been identified as limited (Ferrer-Serrano et al., 2021); second, because the ecosystem is dynamic, it is constantly changing very fast; and third, it is complex because more and more actors are getting involved in it. This complexity has led to attempt to understand how the relationships between the different agents are established and how resources and capabilities are transferred between those agents to increase innovation performance taking into account regional specificities (Cooke, 1992). This idea of collaboration to achieve innovation defends those networks that are needed to create relationships and to enable the generation of flows that in the end, will drive innovation (Boschma & Ter Wal, 2007; Gertler & Levitte, 2005).

Our starting point is to consider that, according to the knowledge-based view (KBV) of the firm (Grant, 1996; Inkpen & Tsang, 2016), knowledge is one of the most relevant intangible assets capable of generate innovation (Tsai, 2001). In a complex ecosystem, having access to external knowledge sources is crucial to be able to respond to the market and societal pressures (Zou & Ghauri, 2008). With this idea is mind, networks can act as structures that facilitate external knowledge flows between the actors embedded them (Khan et al., 2015).

The empirical evidence in this area takes into consideration relevant concepts linked to the study of networks such as actor embeddedness (Giulliani & Bell, 2005; Vicente et al., 2011), or actor proximity (Boschma & Ter Wal, 2007; Morrison, 2008) as characteristics of knowledge networks that stimulate knowledge exchange. In these studies, the authors pointed out that the position that an agent occupies in a network is crucial for innovation performance, because it will determine the access to external knowledge (Chen & Hung, 2010; Villasalero, 2013). Other studies have tried to examine how leadership influences innovation though collaboration, finding the importance for the presence of a leader that stimulates the creation of relationships (Szatmari et al., 2021). In addition, other researchers have concluded that agents who are more participative on networks will have more likelihood of getting resources from outside and, consequently the innovation performance will be improved (Tsouri & Pagoretti, 2021).

Despite the growing interest in this literature stream, most scholars have examined the network structure in specific contexts (Buchmann & Kaiser, 2019; Graf and Broekel, 2012; Szatmari et al., 2021; Tsouri & Pagoretti, 2021), which may have resulted into missing the complexity of innovation systems. Also, there have been relatively few attempts to date to incorpòrate the temporal dimension. In particular, the geographical dimension of phenomena such as knowledge collaborations is of special interest to understand the spatial diffusion of knowledge as it has relevant policy implications, for example, regarding the spatial scale of innovation systems and knowledge interactions (Scherngell & Barber, 2011). Actually, previous studies have called for further research to analyse the complexities of innovation in international settings from a dynamic and structural perspective (Ferrer-Serrano et al., 2022; Volberda et al., 2014) as knowledge networks are considered essential components of regional innovation systems (RISs) as they determine the intensity, type and direction of knowledge diffusion (Doloreux & Parto, 2005; Höglund & Linton, 2018).

In this study, we elaborate on this idea and we attempt to deepen the understanding of the structure of regional knowledge networks. We analyse how the position, the leadership role and the active participation of a given territory influence innovation in this territory. This study argues that regional innovation capacity depends on a complex set of collaborative network variables that, in no small measure, are contingent on the places where agents are located and will determine the capacity to innovate. We also study the role of transferring knowledge across networks. We argue that having KT capacity will strengthen innovation, acting as a mediating factor in our model as other studies have previously pointed out (Maurer et al., 2011).

So three main questions arise at this point. First is the extent to which a particular structure of a knowledge network that is primarily reliant on collaboration drives more innovation capacity. In this study we aim to understand the drivers of innovation capacity across European regions, assessing how the characteristics of a network enhance it. Second, we want to understand what the importance is of having KT capacity for the innovation generation. Finally, we want to understand and evaluate the most relevant European innovative strategy to date in order to suggest policy lines of action.

To answer these questions, a complex network analysis and empirical study is conducted making use of European collaborative projects from 2014 to 2020. A total of 8,424 collaboration projects, in which 14,608 companies from 232 European regions (NUTS2) have participated, have been analysed. This database is particularly useful for the purposes of our work for several reasons. First, it provides information from a complex ecosystem that involves different actors, countries and industries. Second, it provides longitudinal information that allows us to make our results robust. And finally, it is original, allowing us to explore a unique setting not explored until now from a macro and dynamic perspective.

The contribution of this work is twofold. Theoretically, it contributes to three streams of literature: the KBV of the firm, the literature based on innovation systems and the networks theory trying to advance a step further in their understanding. Empirically, a two-stage empirical study is proposed that makes use of a large sample of data on collaborative projects in a dynamic international knowledge network.

Following this introduction, the paper is structured as follows. Section 2 discusses the theoretical background. Section 3 develops a set of hypotheses to be explored. Section 4 presents the sample and methods used to test our hypotheses, while results are explained in Section 5. Finally, Section 6 discusses the conceptual and policy implications of our findings.

2. Theoretical background

2.1. Innovation and Regional Innovation Systems

Innovation systems are increasingly evolving towards being more collaborative (Chen et al., 2019) and knowledge transfer (KT) is crucial in this new setting. Previous studies on innovation systems have mostly focused on the organisational level, showing how companies that are capable of transferring knowledge have improved their innovative performance (Gilbert & Cordey-Hayes, 1996). The reason behind is that, through collaboration, companies gain access to external knowledge that would otherwise not be accessible. These knowledge sources provide resources and capabilities that may eventually lead to new (or improved) products or services and thus sustainable competitive advantages (Zhang & Zhang, 2018).

In view of the importance of collaboration, policy-makers have launched different initiatives that foster innovation through the development of collaboration. The European Commission (EC) has been encouraging and subsidising research collaboration across its member states for more than three decades with the aim of improving knowledge bridges and fostering KT (Veugelers et al., 2015). The goal of this endeavour has been to strengthen European integration and cooperation as well as to foster innovation and ensure Europe’s competitiveness (Szücs, 2020). First, the so-called Framework Programmes (FPs) in the 1980s were budgeted with more than ten billion Euros, the Seventh Framework Programme (FP7), from 2007 to 2013, received about fifty billion Euros, the Horizon 2020 (H2020) programme (2014-2020), around eighty billion Euros and its successor, Horizon Europe (2021-2027) is expected to allocate more than a hundred billion Euros.

This idea of fostering collaboration to strengthen innovation is based on the literature on innovation systems (Lundvall, 1992) and RISs[6], which explains that innovation is embedded in the regional territory in which companies are located (Cooke, 1992). In recent decades, supranational institutions have focused their attention on improving, developing and strengthening RISs. This concept has attracted widespread attention from policy-makers and researchers as a valuable framework for the study and understanding of innovation processes within regional economies (Doloreux & Parto, 2005; Höglund & Linton, 2018).

The central argument underpinning this conceptualisation is that regional actors do not innovate in isolation but in cooperation and interaction with other actors within or outside the region (Höglund & Linton, 2018). This implies that the innovation capacity of a regional actor is embedded in the innovation capacities of other regional actors and in the type of relationships developed between them (Doloreux & Parto, 2005). In other words, innovation will be determined by the technological and institutional capabilities of the economic agents that set up the regions (Hervás-Oliver et al., 2021; Parrilli et al., 2020).

2.2. Knowledge networks and Regional Innovation Systems

According to the KBV, knowledge networks are one of the essential components of technological and industrial ecosystems (Giuliani & Bell, 2005; Morrison & Rabellotti, 2009). They are particularly important for the development of RISs, as they determine the intensity, type and direction of knowledge flows (He & Hosein Fallah, 2009). A key idea in the RIS literature is that the functioning of an RIS depends on the successful development of the system's key resources and the interaction between them (Höglund &

[6] We define an RIS as an "interacting knowledge generation and exploitation subsystem linked to the global, national and other regional systems" (Cooke, 2004, p. 3).

Linton, 2018). In many cases, the interaction between internal and external knowledge networks influences the long-term success of the RIS (Bathelt et al., 2004). Therefore, the inflow of external knowledge is as important as its internal diffusion, as both avoid situations of general blocking of the innovation processes (Broekel & Graf, 2012).

Thus, RISs use knowledge networks to generate, disseminate, apply or exploit knowledge at regional, national and international levels (Stuck et al., 2016). The networking element therefore appears to be important for the creation of new knowledge and its transfer as knowledge networks act as facilitators, channelling knowledge flows (Boschma & Ter Wal, 2007; Gertler & Levitte, 2005; Owen-Smith & Powell, 2004). In the context of an RIS, one of the key features is the creation of local knowledge that is not explicitly articulated between RIS organisations. If the knowledge produced within the RIS is combined with that of other regions or markets, value can be created that fosters innovation both locally and globally (Bathelt et al., 2004).

Berman et al. (2020) pointed out that although local knowledge munificence is a necessary condition for a region to achieve and sustain a leading position in the global knowledge development process, it is no longer sufficient. They found that the connectivity of actors and the consequent flow of knowledge has become increasingly central to economic success for regions. Therefore, it is crucial for achieving innovation to operate widespread collaboration networks to facilitate the flow of knowledge from different parts of the world (Isaksen & Karlsen, 2016).

For analytical purposes, RISs have been conceptualised as being composed of nested subsystems (Binz et al., 2014). The functioning of an RIS depends on the successful interaction between the subsystems and the ability of actors to access resources outside their own territory (Bergek et al., 2015). The interaction between these subsystems is referred to as structural couplings (Binz & Truffer, 2017). Structural couplings are important not only for the functioning of the system but also for the actors in the knowledge network, allowing them to connect knowledge from an RIS to market segments in distant places. Resources tend to develop asymmetrically within an RIS given the different territorial preconditions, such us knowledge development and transfer (Binz et al., 2014). Due to this irregular distribution, firms may not have local access to all the resources in the system. Therefore, firms will have to establish extraterritorial couplings to access other system resources in the RIS (Binz & Truffer, 2017). Networks are therefore a particularly important type of structural coupling in RIS.

3. Hypotheses

3.1. Network structure properties and innovation

Position in the network

The literature has traditionally suggested that all actors in an RIS benefit from the regional knowledge network because it is assumed that all regional actors are equally embedded within it (Asheim, 1994). However, empirical studies have presented strong evidence of significant heterogeneity in this embeddedness (Boschma & Ter Wal, 2007; Stuck et al., 2016). That is, there are actors within the regional knowledge network that adopt a key role and influence or are influenced to a greater extent by the developed relationships. These actors can be considered as having a privileged position (Tsouri & Pegoretti, 2021) within the network in terms of connectivity (Berman et al., 2020). The privileged position of an actor constitutes an attractive attribute resulting from centrality (Barabási & Albert, 1999; Papadopoulos et al., 2012). These central actors are important for KT as they act as intermediaries and accumulate knowledge over time. Their role becomes key to the KT and subsequent innovation (Autant-Bernard et al., 2014; Wanzenboeck et al., 2014). As a consequence, actors with a high centrality or, in other words, who are centrally located, provide a number of opportunities to foster the process of knowledge creation and diffusion, gaining easier access to knowledge resources, benefiting from their direct or indirect collaboration with a variety of actors and thus having an impact on the structure and functionality of the regional knowledge network (Balland et al., 2016; Ter Wal, 2013).

The relationship between the centrality of network agents and innovation has attracted the attention of academics over the last few years. Buchmann and Kaiser (2019) focused on the German biotech industry and found that it is the higher centrality in the agent that significantly increases innovation success. Tsouri et al. (2021) analysed the case of offshore wind and concluded that different types of knowledge networks and the location of the agents facilitate market access and structural coupling to varying extents. Berman et al. (2020) and Tsouri and Pegoretti (2021) focused their studies on understanding the Italian knowledge network, finding the importance of being well connected with the rest of the agents to achieve innovation.

Although in most cases this relationship has been analysed from a micro perspective, in recent years there have been some scholars who have tried to approach it from a global and macro approach (Ferrer-Serrano et al., 2021; Neuländtner & Scherngell, 2022). These few papers seem to point to a direct and positive relationship between the centrality of agents in a knowledge network and innovative outcomes. In particular, Neuländtner and Scherngell (2022) revealed interesting differences between regions that use networks to exploit and to explore knowledge creation. They concluded that regions with higher centrality or that are surrounded by high centrality neighbours benefit more from networks. However, limitations in the studies have been highlighted by focusing on a particular industry or region due to the lack of generalisation of findings. We therefore argue that:

H1. *The greater the privileged position in the knowledge network, the better the innovation capacity of a regional system.*

Leadership in the network

Leadership is about motivating and leading project participants to realise their potential and achieve tougher and more challenging organisational missions. The leader's ability is therefore critical to reach a goal successfully (Bakar & Mahmood, 2014). Leadership is concerned with making decisions about processes and functions to improve efficiency, taking on such functions as planning, controlling and coordinating (Nishimura & Okamuro, 2018). Zhu and Cheng (2015) concluded that leadership can provide a balance between autonomy and control, encourage members' participation and benefit innovation.

Davis and Eisenhardt (2011) pioneered the study of leadership when studying interfirm collaboration for innovation. They concluded that leadership is crucial for the achievement of innovation because a leader will foster collaboration through motivation. Depending on the kind of relationships fostered, the type of leadership will be different. In this regard, Alberti et al. (2021) pointed out the existence of a strong positive correlation between rotational leadership[7] in organisational knowledge networks and innovation. Furthermore, Szatmari et al. (2021) explored how the status of the project leader affects the performance of innovation projects in the video game industry. They found that an intermediate level of status was positively associated with average project performance. They also revealed more extreme performance effects for high-status leaders.

[7] Decision control shifts among partners at different phases of the collaboration.

However, the role of leadership in RIS contexts has hardly been discussed, and results do not add up to a common conclusion (Rosing et al., 2011). The previous arguments suggest that there is evidence of a positive relationship between leadership and the achievement of innovation, although results are not generalisable. It seems that the leader plays an important role in the innovation performance of the group to which it belongs (Martiskainen, 2017) as leadership has been identified as one of the key factors influencing an innovation system (Marjanovic et al., 2020).

As argued above, regions represent a set of individuals that build through their specificities the regional structure. In this line of thought, when we translate these arguments to the context of an RIS, we argue that having a leading position in an RIS will increase the legitimacy of that region with respect to the rest of the regions involved and that it will be therefore perceived as an interesting agent with which to collaborate, reinforcing its leadership role and allowing it to obtain greater resources and capabilities. As a consequence, this will positively impact the innovative results of a region. Thus, we propose the second hypothesis:

H2. *Being a regional leader in the knowledge network increases the innovation capacity of a regional system.*

Degree of participation in the network

From a structural network perspective, actors that participate intensively in various collaborative arrangements are directly interconnected with others, benefit from short pathways to various sets of networks nodes and are thus highly integrated into the network structure. In this sense, one of the most frequent indicators of learning is the development of knowledge through the intensity of collaborative participation (Colombo et al., 2016).

These strategic collaborations help to maximise collective resources and increase the performance of individual actors. In this way, networks allow them to pool their resources on projects that are too large for firms to undertake on their own, achieving economies of scale (Hagedoorn et al., 2000; Wanzenböck et al., 2015). Therefore, firms that participate in collaborative networks, not only improve their innovative performance but also gain access to external markets (Tsouri et al., 2021) opening up new opportunities to access resources and thus improving the level of competitiveness.

At the regional level, organisations' network relationships are also crucial assets for their regional environments (Wanzenboeck et al., 2014). Participating actively in interregional networks provides the opportunity to quickly access specific knowledge resources outside the regional boundaries and supply localised actors with knowledge located at a greater geographical distance (Bathelt et al., 2004). Empirical studies dealing with interregional knowledge relationships typically address a particular type of network, and although they are usually focused on a country or industry (Broekel & Graf, 2012; Tsouri & Pagoretti, 2021) or on specific agents (Hoekman et al., 2010), they typically find a positive relation between the participation in those networks and innovation performance. By way of example, Tsouri and Pagoretti (2021) found that active participation in the Norwegian offshore wind network benefits R&D collaborations and access to external markets.

Regional participation in collaborative networks has previously been studied in a generic and holistic way, but it has not been analysed as a variable in knowledge network structure. We believe that those RISs that are more participative in the KT network will have a greater capacity to take advantage of the synergies and economies of scale that they offer; as a consequence, their innovative results will be greater. For this reason, we posit the following:

H3. *Participating in the knowledge network, positively affects the innovation capacity of a regional system.*

3.2. The mediation effect of KT capacity

Previous literature has struggled to explain the role of knowledge externalities in policy outcomes of regional innovation networks (Fernandes et al., 2021). However, to our knowledge, the ability to transfer knowledge, i.e., to be actively part of knowledge exchange processes, have not been explicitly measured in the RIS literature.

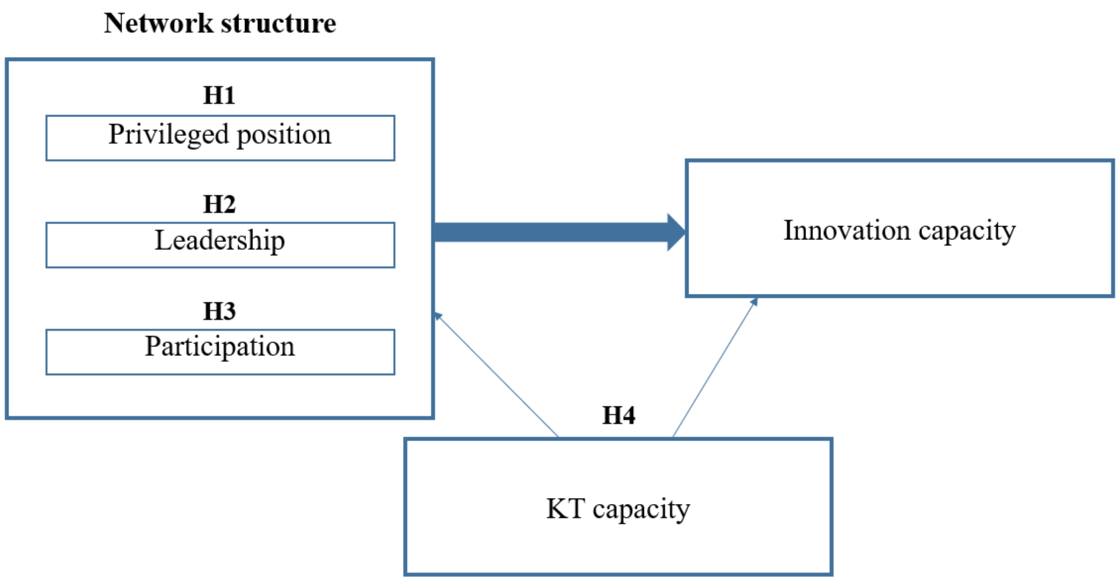
The ideas presented in the previous sections highlight that KT is an important mechanism underlying innovation in RISs. In this sense, we would like to demonstrate that the ability of a region to take part in KT processes strengthens the effect of having adequate network structure properties on innovation capacity. In fact, the arguments provided lead us to believe that regions that are structurally better positioned in the network, with a leader role and greater participation, should benefit more from the existence of knowledge flows. On the other hand, regions with a worse network structure would suffer the disadvantage of not being able to access or generate KT, and consequently their innovative capacity would be lower. Therefore, KT capacity should contribute to the explanation of the above relationships.

We consider that part of the positive effect we theorised in the previous hypotheses on network structure and innovation may be partly explained by being more or less able to transfer knowledge. In other words, we believe that the fact that an RIS has a central, leading and participative position has a positive impact on the innovation capacity of that system but that this impact will be affected if the RIS is capable of transferring knowledge to other RISs while, at the same time, receiving external knowledge.

In sum, the network-based literature seems to point out that, among other explanations, the contribution of KT capability to the explanation of regional innovation should take place through mediation (Maurer et al., 2011). In other words, their influence seems to take place in a sequence. In the first stage, the KT capability of a region is determined by the position, role and level of participation in the complex knowledge network. In the second, KT capacity explains the region's innovation capacity. Therefore, occupying an appropriate position would only have an indirect effect on the innovation of the regional system. All the above reasoning leads to our fourth hypothesis:

H4. *The relationship between having a privileged position, leadership role and being participative in the knowledge network and innovation capacity, are mediated by having KT capacity; that is, they are explained by KT capacity across a regional system.*

Figure 29. Conceptual model



4. Data and methodology

4.1. Data sources

KT and network structure data

The previous hypotheses will be tested within the context of the H2020 strategy. According to the EC, H2020 was the biggest European Union research and innovation funding programme from 2014-2020 with a budget of nearly €80 billion. This initiative was born to boost Europe’s competitiveness through the collaboration of organisations, that is, to promote inter-organisational and international KT through the development of innovative projects based on the achievement of excellent science, industrial leadership and tackling societal challenges. Given the collaborative nature of this initiative, several studies have used H2020 data to analyse KT (Enger, 2018; Ferrer-Serrano et al., 2021; Grimpe et al., 2021).

The H2020 initiative is structured according to three pillars. The "Excellent Science" pillar is based on the generation of scientific and academic knowledge, with the industrial perspective relegated to second place. The "Industrial Leadership" pillar aims to accelerate the development of technologies and innovation in European industries. And the "Social Challenges" pillar seeks to address European problems from a social rather than an industrial perspective. For the development of this paper, given our focus, projects under the category "Industrial Leadership" have been considered (2014-2020). Table 18 describes the main thematic priorities of projects that fall under this pillar. The development of innovation related with “Information and Communication Technologies” (ICTs) is the main focus of Europe, as it attracts most of the contribution and number of projects followed by projects that foster innovation for SMEs as well as innovation related to advanced processes and materials among others.

Table 18. Main thematic priorities in Industrial Leadership projects (H2020)

Thematic Priority Description	Participation	Net EU contribution (€)
Information and Communication Technologies	19,373	7.11B
Innovation in SMEs	5,850	1.7B
Advanced manufacturing and processing	4,445	1.22B
Advanced materials	3,261	1.72B
Space	3,202	967.45M
Nanotechnologies	1,555	592.52M
Biotechnology	1,004	425.88M
Access to risk finance	51	9.72M
Leadership in enabling and industrial technologies	41	56.62M

To operationalise our data, we first screened the projects, considering just the ones coordinated by an organisation from a European country[8]. Second, we exclusively considered projects with at least two organisations involved to ensure that a knowledge flow was taking place (8,424 projects). Finally, as we used regions as the unit of analysis, we matched each organisation with the region where they were located[9], allowing us to identify knowledge flows between regions.

In order to understand the direction of the knowledge flows, we considered our graph as directed. Notice that as in a knowledge network based on research projects, the participating actors may occupy the role of coordinators or merely executors. In our case, we considered the origin the coordinating region, and the destiny, the executor region.

RIS and innovation capacity data

We have employed indicators extracted from the European Innovation Scoreboard produced by the EC. We have used the indicators regionalised by the Regional Innovation Scoreboard initiative as previous literature have done (Hervás-Oliver et al., 2021). This initiative, which aims to capture the capacity of different European RISs, uses primarily CIS (Community of Innovation Survey) data to build

[8] More information in Appendix II.
[9] H2020 provides the address of the offices involved in the project, so that if it is a subsidiary that is part of project, its address and therefore the region in which it is located is taken into consideration.

regional indicators and distinguish between advanced (leader and strong innovators) and less-advanced regions (moderate and emerging innovators). This is crucial for this paper since the aim is to identify how innovation capacity depends to a large extent on the characteristics of the collaboration dynamics of its regional technological and institutional ecosystem.

Regions in Europe differ in their innovative capacity because of their distinct resource endowments that depend, among other factors, on their levels of development. In particular, the RIS dataset includes information about framework conditions, investments, innovation activities and its impacts[10]. Variation in development affects the innovation capacity of organisations located in each territory. The RIS 2021 —including 2014–2020 data— covers 232 regions across 25 European countries[11]. The RIS data are categorised on a scale between 1 and 12, with the aim of producing a composite indicator integrating variables from different scales.

4.2. Sample and methods

Variables

Dependent variable

Innovation capacity. We measured innovation capacity though the unweighted average of the scores of 21 indicators[10]. It synthesised the regions' innovative capacity with respect to four different categories: framework conditions, investments, innovation activities and impacts. The result was a continuous variable that ranges from 1 (emerging innovator) to 12 (leader innovator). This index has been used and validated by previous works that analyse the innovative capacity of regions (Hervás-Oliver et al., 2021).

[10] For further details, see Appendix I.
[11] More information in Appendix II.

Independent variables

Privileged position. This was measured with the PageRank, also well known as eigenvector centrality. It is the node's importance while giving consideration to the importance of its neighbours (Golbeck, 2013). PageRank considers (1) the number of in-bound links, (2) the quality of the linkers, and (3) the link propensity of the linkers (Hansen et al., 2020). Actors with a high value on this measure are connected to other nodes that are themselves highly relevant, or to many other nodes, perhaps less relevant. If a node is pointed to by many nodes (which also have high eigenvector centrality), then that node will have high eigenvector centrality. Therefore, the position occupied by agents with a high value in this measure will have a privileged position in the knowledge network.

Let EC (G) be the centrality of a vector associated with a network G; the crux is that the centrality of a node is proportional to the sum of the centrality of its neighbours. Its representation is:

$$\lambda \cdot \; EC^{v_i}(G) = \sum_{v_j} g_{ij} EC^{v_j}(G)$$

in which gij takes the value 1 if (vi, vj) ∈ E and 0 otherwise and k is a proportional factor. This variable was normalised to adopt values between 0 and 1.

Leadership. This variable was measured through the out-degree centrality (Lee et al., 2010; Rehman et al., 2020). It represents the number of occasions in which a region occupies a coordination role in the knowledge network, that is, the number of outward directed graph edges from a given graph vertex in a directed graph, or in other words, the number of connections that originate from a vertex and point outward to other vertices (Hansen et al., 2020). As we considered the graph has a direction flow (from the coordinator or leader of the project to the executors), this metric allowed us to measure the knowledge flow from the leader to the rest of the agents. This variable was normalised for values between 0 and 1.

Participation. Participation was measured as the degree centrality of a region in the whole knowledge network (Freeman, 1977), which identifies the number of links a node has (inflows and outflows). This variable measures the level of active participation in the knowledge network, whatever the role may be (coordinator or executor). Degree centrality allows to examine the level of participation in the knowledge network defined as:

$$DC^{v_i} = \frac{d(v_i)}{|V| - 1}$$

where *d (vi)* denotes the degree of centrality of the node *vi* in the network. This variable was normalised for values between 0 and 1.

Knowledge transfer capacity. This variable was measured through betweenness centrality. This variable quantifies the frequency or number of times a node is between the two agents or shortest paths of other actors. An agent with greater intermediation power would have more control over the network because more information will pass through that agent; or in short, it will have a greater capacity to transfer knowledge. It is a measure used in the previous literature to understand intermediary flows in a network (Tutzauer, 2007). It can be formally defined as follows:

$$g(v) = \sum_{s \neq v \neq t} \frac{\delta_{st}(v)}{\delta_{st}}$$

Where δ_{st} is the total number of shortest paths from node *s* to node *t* and $\delta_{st}(v)$ is the number of such paths passing through v. This variable was normalised for values between 0 and 1.

Control variables

Our model also controlled for a set of variables that previous literature had identified as influencing our dependent variable. Several studies have suggested that there is a positive relationship between GDP per capita in a region and its innovativeness (Turkina et al., 2019). Similarly, the literature has also argued that R&D investment increases the innovation capacity of regions (Turkina et al., 2019). Zang et al. (2018), found that countries with a higher level of education have a higher innovation capacity. In this sense, we controlled for the percentage of graduates with tertiary education. Finally, we control for the population size of the region and density of population (Hamidi et al., 2019; Zang et al., 2018).

Sample and methods

A two-stage analysis was performed, making use of European collaborative projects from 2014 to 2020. A total of 8,424 collaboration projects, in which 14,608 companies from 232 European regions participated were analysed. First, a complex network analysis was conducted for the extraction of the structural network variables. Second, we built a panel with a total number of observations that amounted to 1,645. This work was in the process of running the second stage econometric models. Since the innovation capacity variable was a double-censored variable, representing the level of innovation ranging between 1 and 12, the applicable methodology was a random effects Tobit regression (Bernal et al., 2019).

5. Results

5.1. Descriptive results

Table 19 shows the descriptive statistics of the sample as well as the correlation matrix. The mean of our dependent variable was 5.979, slightly below of the centre of the scale, with a standard deviation of 2.965. As explained before, all our independent variables, were normalised between 0 and 1. All of them had low means and standard deviation. That means that in general terms, the level of leadership was quite low. The same happened with the participation. If we delve more deeply into our data set, we notice that just a few regions concentrated the leadership and participation power of the projects, while the rest occupied a more discrete positions, acting simply as projects executors.

Finally, in order to check for multicollinearity problems, the variance inflation factors (VIFs) were computed to assess the severity of multicollinearity. The average VIF value was 3.149[12], which is below the cut-off point of 10 (Chatterjee et al., 2000), a fact that means that multicollinearity was not a serious issue and all the variables can be included in the same regression.

[12] The maximum VIF is 5.150, also below the cut-off point of 10.

Table 19. Descriptive statistics and correlations

	Variables	n	Mean	Std. Dev	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Innovation capacity	1,645	5.979	2.965	1	12	1.000									
(2)	Privileged position	1,645	0.374	0.236	0	1	0.410*	1.000								
(3)	Leadership	1,645	0.074	0.145	0	1	0.305*	0.675*	1.000							
(4)	Participation	1,645	0.095	0.147	0	1	0.365*	0.579*	0.655*	1.000						
(5)	KT capacity	1,645	0.122	0.262	0	1	0.294*	0.561*	0.446*	0.485*	1.000					
(6)	GDP pc (000)	1,645	35.929	18.610	7.075	97.019	0.768*	0.177*	0.111*	0.136*	0.063	1.000				
(7)	R&D expenditure	1,577	1.889	0.839	0.382	3.527	0.741*	0.157*	0.088*	0.120*	0.069	0.705*	1.000			
(8)	Population (000)	1,611	2,218	2,001	83.870	23,058.077	0.212*	0.419*	0.325*	0.379*	0.344*	-0.006	0.001	1.000		
(9)	Tertiary education	1,619	30.136	9.704	11.4	59.6	0.624*	0.370*	0.327*	0.385*	0.326*	0.488*	0.273*	0.182*	1.000	
(10)	Population density	1,380	350.278	871.781	3.4	7526.7	0.164*	0.213*	0.173*	0.208*	0.237*	0.030	0.063	0.093*	0.256*	1.000

* p<0.1

5.2. Econometric model

Table 20 shows the Tobit estimates for the relationship between network structure variables and innovation capacity. We run four nested models. Model 1 is the base model which only included the control variables. Model 2 introduces the direct effects of leadership, position and participation. Model 3 also includes the mediation effect of KT capacity on the direct effects. Finally, Model 4 aggregates the independent variables into one named network structure and shows the mediation effect. It is important to note that if we compare the models through the Wald test –shown at the end of Table 20-, the third model has less explanatory power. So our discussion will be focused on the second and the fourth one to explain our results.

According to Model 1 all the control variables have significant and positive effect on innovation capacity. Specifically, GDP per capita increases innovation capacity in line with previous studies (Turkina et al., 2019). Expenditure on R&D also has a positive and significant effect, which is consistent with previous literature (Turkina et al., 2019). Regions with a higher proportion of people with tertiary education also have a positive and significant effect on innovation capacity. This result is also in line with what previous research has identified. Population has a negative and significant effect on our dependent variable, contrary to previous literature. Finally, population density has a negative and significant effect as Hamidi et al. (2019) and Zang et al. (2018) have pointed out. The sign and significance of the control variables remain notably stable (the only exception is tertiary education in Model 4).

In Model 2, the three independent variables that approach the structure of the network presented a positive and significant effect on innovation capacity. First, having a higher centrality position positively influences the innovation capacity of a regional system (β = 0.00072; p < 0.05), thus offering support for H1. This finding is consistent with previous literature that highlighted the power of centrality in a network in particular contexts and industries. Second, we hypothesize that those regions with higher levels of leadership in the network will have higher innovation capacity. The results show a positive and significant effect (β = 0.0059; p < 0.1), thus giving support to H2. Finally, participating actively in a knowledge network, no matter the role in that network, increases the innovation capacity of regional systems (β = 0.00225; p < 0.001). This result is in line with our H3.

To test the mediation effect, we run two different models. Model 3, with less explanatory power, does not support H4. We argued that KT could act as a mediator to the three independent variables of our model. However, although the variable is statistically significant and positive, we do not find that strengthening effect over the direct effects. We then group the independent variables into one as the three of them try to explain structural components of the knowledge network, and we regress the estimation to see the aggregate effect on them. Interestingly, it is the model with the higher explanatory power and we observe that KT in this model was acting as a mediator to the relation between network structure components and innovation capacity (β = 0.00263; p < 0.001 to 0.0058; p < 0.001). So, we can extract from this result that H4 is partially supported.

Table 20. Random effects Tobit regression

	Model (1)	Model (2)	Model (3)	Model (4)
Position		0.00072**	0.00042**	
		(0.00043)	(0.00044)	
Leadership		0.00059*	0.00068*	
		(0.00091)	(0.00082)	
Participation		0.00225***	0.00205**	
		(0.00107)	(0.00106)	
Network structure				0.0058***
				(0.00181)
KT capacity			0.00169***	0.00263***
			(0.00055)	(0.00062)
GDP per capita	0.0409***	0.0212***	0.0198***	0.0337***
	(0.00182)	(0.00067)	(0.00077)	(0.00134)
R&D expenditure	0.0807***	0.0431***	0.0397***	0.0656***
	(0.00154)	(0.00059)	(0.00068)	(0.00132)
Population	-0.0134***	-0.00830***	-0.00718***	-0.0100***
	(0.00101)	(0.00057)	(0.00043)	(0.0008)
Tertiary education	0.0128***	0.00491***	0.00708***	0.00185
	(0.00121)	(0.000636)	(0.00059)	(0.00121)
Population density	-0.00013***	-0.00021***	-0.00033***	-0.00093***
	(0.00091)	(0.00063)	(0.00059)	(0.00107)
Constant	-0.0054***	-0.0027***	-0.0017***	-0.0066***
	(0.00126)	(0.00054)	(0.00057)	(0.00119)
Log likelihood	3041.849	3907.074	3959.280	3965.602
Wald chi-square	19922.18***	21739.82***	15873.83***	21766.14***
Observations	1,645	1,645	1,645	1,645
N	232	232	232	232

*** p<0.01, ** p<0.05, * p<0.1

To better understand the mediation effect, we perform an addition analysis based on Baron and Kenny (1986). Three conditions must apply: first, independent variables must affect the mediator, second, the mediator must affect the dependent variable and third, when including the mediating effect, previously significant relationships between independent and dependent variables should be eliminated or substantially reduced. Results of these three conditions are presented in Table 21.

Regarding testing mediation, the model fulfills the three considerations proposed by Baron and Kenny (1986). The model meets the first of the conditions, where network structure is the independent variable and influence dependent variable innovation capacity. The second condition also meet, as the mediator variable influence the dependent variable in a positive and significant manner. Finally, when the mediator variable is added to the model, the influence of network structure on innovation capacity diminish; that is, the direct effect of our dependent variable is lower than the total effect. Given that all of the conditions are satisfied but the influence of the dependent variable remains significant in the presence of the mediator, we are facing a partially mediated model.

Table 21. Test of Mediation. Comparison of standardized path coefficients for direct and mediation models

Path	**Direct model**	**Direct model (2)**	**Mediation model**
Network structure → Innovation capacity	0.00187***		0.00105***
KT capacity → Innovation capacity		0.00254***	0.00251***
Network structure → KT capacity → Innovation capacity			0.00294***

*** p<0.01, ** p<0.05, * p<0.1

Table 22. Equation-level goodness of fit

	Variance			**R-squared**	**MC**	**MC2**
	Fitted	**Predicted**	**Residual**			
Network structure → KT capacity	0.999	0.475	0.524	0.476	0.690	0.476
Network structure → Innovation capacity	0.999	0.166	0.835	0.166	0.407	0.166
Overall				**0.521**		

The model is not fully mediated because network structure has its own direct effect on innovation capacity, in addition to the indirect effect through the mediator (see

Table 21). This result suggests that the network structure is the initial part of the process of regional innovation capacity. Network structure influences innovation capacity by itself, but it could also result in a greater integration through KT flows and consequently an additional positive effect on innovation capacity. Indeed, the 52.1% of the independent variables over the dependent variable can be explained by the mediation (Table 22).

Additional analysis

To gain a better understanding of the effects of the model, an additional analysis based on variance differences (ANOVA) is performed. For this purpose, the independent and dependent variables are categorised into four categories (from low to high in the case of the independent variables and following the original classification of the Regional Innovation Scoreboard, from emerging innovator to leader innovator for the dependent variable).

Table 23 shows the existence of significant differences in all groups of the independent variables with respect to the dependent variable, with notable intergroup variances in the case of the position variable. In the case of the intermediate levels of the leadership and participation variables, the variation is more discrete but equally significant. A posthoc HSD Tukey test is carried out (see Appendix III), allowing us to verify the significance of the differences between conditions.

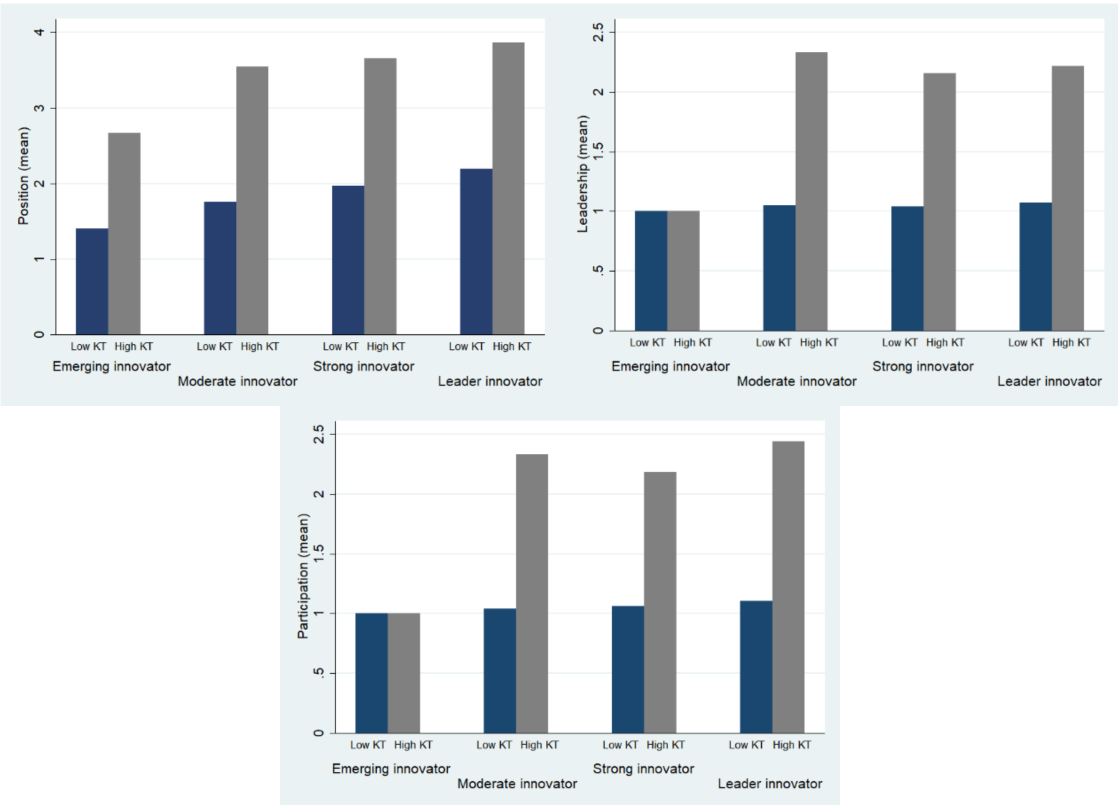
Table 23. One-factor ANOVA

Position	**(1) IC**	**Participation**	**(2) IC**	**Leadership**	**(3) IC**
Low	1.856***	Low	2.207***	Low	2.235***
	(0.038)		(0.026)		(0.026)
Moderate -	2.399***	Moderate -	3.129***	Moderate -	3.008***
	(0.037)		(0.084)		(0.093)
Moderate +	2.812***	Moderate +	3.137***	Moderate +	3.089***
	(0.071)		(0.140)		(0.151)
High	3.152***	High	3.800***	High	3.429***
	(0.073)		(0.446)		(0.383)

*** p<0.01, ** p<0.05, * p<0.1

Figure 30 displays these differences and incorporates the KT capacity mediation effect (categorised by low and high levels of KT capacity). First, the mediation effect is reflected in almost all situations, lending support to H4, except when we look at the effect of leadership and participation on regional emerging innovators (the KT mediation effect in these cases remain stable). Second, we see, according to our hypotheses, the positive effect of our independent variables on innovation capacity. That is, we can see through these representations how regions with a higher level of innovation capacity tend to have a better position and leadership level and how they actively participate more, thus supporting H1, H2 and H3.

Figure 30. ANOVA model representation



6. Discussion and conclusions

This study has sought to gain a better understanding of the effect of the structure of collaborative networks on regional innovation capacity in Europe. Following previous contributions (Parrilli et al., 2020), we have tried to determine whether three of the most widely used variables in the study of complex networks act as drivers in RISs and how they vary according to their intensity. In addition, we have studied the role played by KT in these collaborative networks and to what extent networks channels knowledge and have an impact on the innovative capacity of the regions.

In doing so, we have answered three questions. First, we have assessed to what extent the innovation capacity of regional systems is explained by the structure that these regions occupy in the European knowledge network. Secondly, we have verified the importance of having KT capacity for innovation generation. Thirdly, we have deepened the understanding of these relationships in the context of the H2020 strategy. In short, this study sheds light on the importance of collaboration as a driver of regional innovation and the importance of networks and their structure in KT.

Our results indicate that regional innovation capacity in Europe is partly driven by collaboration between agents in the knowledge network. In this sense, we contribute to innovation systems literature, showing evidence of the innovation policy strategies evolution (Hervás-Oliver et al., 2021). It is no longer just important to invest in internal R&D, but it is crucial to strengthen the relationships between the agents that make up the ecosystem; in this regard, we provide solid evidence. Previous studies already pointed to these conclusions in particular contexts such as offshore wind (Tsouri et al., 2021), indicating that the emphasis on R&D as the main input in the innovation process has proven to be far from the best way to advance innovation, especially for less innovative regions (Hervás-Oliver et al., 2021) that are likely to have more limited organisational structures and resources. In this sense, regional particularities influence how firms innovate (Cooke, 1992; Parrilli & Alcalde, 2016), especially in a knowledge-based economy.

These particularities between regions entail that understanding an ecosystem network structure is relevant to establishing policies that contribute to the improvement of innovation capacity. First, this work, in line with similar results obtained within the context of specific industries or companies, provides evidence that having a central position with respect to your neighbours influences positively regional innovative capacity. This reinforces the importance of positioning oneself in the right place and with the innovation system agents of the greatest interest.

Secondly, we found that greater active participation in the knowledge network helps to develop the innovation capacity of a regional system. In other words, it is important to participate, actively or passively, in the collaborative network. Innovation is nourished by knowledge, and although participation in a research project sometimes does not obtain a direct economic return, our results indicate that the return in terms of access to knowledge is relevant for the generation of innovation. Otherwise, without participation, access to knowledge would not be possible due to the regional boundaries.

Thirdly, there is evidence that occupying a position of leadership (or coordination) in a knowledge network has an impact on regional innovation capacity. Regions that play a leading role in the network will benefit the most in terms of their innovation capacity. The explanation can be found in the knowledge centralisation role of research project leaders. Among other functions, a project coordinator centralises and organises information and resources, which can help to generate more trusting relationships, and in turn, to acquire external knowledge more easily, helping to develop the innovation capacity of the territory.

Our results also suggest that not only is it important to have adequate network properties, but it is also important for the networks to act as a channel through which knowledge is transferred. In this sense, regions with greater KT capacity find that their innovation capacity is greater. This conclusion allows us to understand innovation as a process (Maurer et al., 2011), which implies that, firstly, it is important to achieve an adequate location in the ecosystem and secondly, it is essential to be able to transfer knowledge and absorb in in order to finally develop innovation capacity.

The main contribution of this research has been the integration of the innovation systems literature into the KBV through the use of network theory. In this way, this study provides answers to some calls in the literature for the development of a more unifying framework of KT that integrates innovation with other important dimensions (Tsouri & Pegoretti, 2021). From an empirical perspective, first we offer a two-steps analysis that have allowed us to understand knowledge flows, the position of each agent in the complex network and the impact on their innovation capacity. Secondly, we incorporate a longitudinal perspective into the analysis by considering that regional innovation capacity and network structural properties can vary over time. Finally, we contribute contextually to the previous literature, which has traditionally focused on the analysis of a particular industry or geographical area, by analysing an international complex knowledge network. In short, this work makes use of an original database to provide robust results in a complex ecosystem.

6.1. Policy implications

From a policy point of view, our results stress the need to develop policies that emphasise collaboration between regions. Therefore, we propose that innovation policies should try to encourage, firstly, participation in collaborative networks. We believe that this research can be useful for policy makers to assist in creating new collaborations in the process of consolidating existing ones. Policy makers can play a relevant role in the creation of a collaborative culture based on trust. They can attract through confidence entities, and they can strengthen linkages between them to enhance the stimulation of KT.

Secondly, innovation policies should try to offer incentives for less innovative regions to also try to achieve coordination positions. We believe that in order to strengthen the leadership position of a region with low innovation, it is essential to provide access to the technical, economic and support infrastructures necessary for the development of innovative initiatives. In addition, we believe it is important to underline the relevance of occupying coordination positions in order to gain access to valuable knowledge pools.

Finally, with the aim of generating strategically attractive relationships with other network agents, it would be interesting to generate a collaborative mapping system that would allow contact with a given network agent according to particular objectives. This information can be helpful in the formulation of an innovation roadmap that would favour the achievement of certain objectives. Once we know which countries or which companies lead the European R&D scene in a given area, it will be easier to develop the appropriate actions to facilitate a firm's own competitiveness or to identify industries that can reach central positions in the networks in the case of receiving initial support.

When designing innovation policies, local policymakers have to take into consideration the strategic behaviour of actors in the KT process inside the network. Since more central actors are the most benefited in terms of innovation, collaboration policies are likely to reinforce their dominance in the network, slowing down the emergence of local peripheral actors and new entrants. We reflect that innovation policy might be even more effective if it targets balanced sub-networks, in order to strengthen the position of the local peripheral actors in the system by, including them in the innovation process.

This would constitute local peripheral actors more attractive for future collaboration with new entrants, strengthening the entire knowledge network, and facilitating KT.

In sum, policy-makers should be responsible for establishing mechanisms to ensure the effectiveness of KT between the players in research programmes. They should also be conscious of the leverage they have when adopting an active role in the innovation ecosystem. There are several dimensions that could be considered to achieve a more cohesive network: conflicts of interest between the parties, lack of resources and bureaucratic obstacles, among others.

6.2. Limitations and future research avenues

Our study is not without limitations. Firstly, the definition we use for knowledge is a proxy that although it has been used previously, presents some limitations. This is a difficulty that knowledge management literature has identified before but it is also a strength that allows us in some way to examine knowledge flows. Future studies should try to offer a more complex measure of knowledge in order to corroborate and go deeper into the analysis of the effect of network structures on innovation capacity. Secondly, we do not consider the nature of the organisations involved. In other words, following previous studies that concluded that the role of agents differs according to its organisational nature (Ferrer-Serrano et al., 2021), we believe that it will be interesting to examine the level of contribution to the regional innovation depending on the organization model. Regions with a higher number of scientific centres or whose universities are more prestigious will probably have better network properties and therefore better innovation capacity. In this line of research, future research could try to understand how networks behave depending on the thematic area of the projects. This would let us understand who the key drivers of innovation systems are in Europe, to check if there are differences between thematic areas and, more importantly, to foster the development of particular policy strategies in the consequent Horizon Europe frame.

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Appendix I

Regional Innovation Index		
Indicators		**Definition**
Framework Conditions		
1	Human Resources	Percentage of population aged 25-34 having completed tertiary education. Lifelong learning, the share of population aged 25-64 enrolled in education or training aimed at improving knowledge, skills and competences.
2	Attractive Research Systems	International scientific co-publications per million population. Scientific publications among the top-10% most cited publications worldwide as percentage of total scientific publications of the country.
3	Digitalisation	Individuals who have above basic overall digital skills. Own estimates using Households with broadband access.
Investments		
1	Finance and Support	R&D expenditure in the public sector as percentage of GDP.
2	Firm Investments	R&D expenditure in the business sector as percentage of GDP. Non-R&D innovation expenditures as percentage of total turnover. Data for SMEs. Innovation expenditures per person employed in innovation-active enterprises. Data for SMEs.
3	Use of ITs	Employed ICT specialists. Estimates using Employment in information and communication.
Innovation Activities		
1	Innovators	SMEs introducing product innovations as percentage of SMEs. SMEs introducing business process innovations as percentage of SMEs.
2	Linkages	Innovative SMEs collaborating with others as percentage of SMEs. Public-private co-publications per million population.
3	Intellectual Assets	PCT patent applications per billion GDP (in Purchasing Power standards). Trademark applications per billion GDP (in Purchasing Power standards). Individual design applications per billion GDP (in Purchasing Power standards).
Impacts		
1	Employment Impacts	Employment in knowledge-intensive activities as percentage of total employment. Employment in medium-high and high-tech manufacturing and knowledge-intensive services. Employment in innovative enterprises. Data for SMEs.
2	Sales Impacts	Sales of new-to-market and new-to-enterprise product innovations as percentage of total turnover. Data for SMEs.
3	Environmental Sustainability	Air emissions in fine particulates (PM2.5) in Industry.

Appendix II

		RIS			RIS			RIS			RIS
		AT1			DE3			ITH5			SI04
1	*Austria*	AT2			DE4			ITI1			ES11
		AT3			DE5			ITI2			ES12
		BE1			DE6			ITI3			ES13
2	*Belgium*	BE2			DE71			ITI4			ES21
		BE3			DE72			ITF1			ES22
		BG31			DE73			ITF2			ES23
		BG32			DE8			ITF3			ES24
3	*Bulgaria*	BG33			DE91			ITF4			ES3
		BG34			DE92			ITF5			ES41
		BG41			DE93			ITF6	21	*Spain*	ES42
		BG42			DE94			ITG1			ES43
		HR02			DEA1			ITG2			ES51
4	*Croatia*	HR03			DEA2	14	*Lithuania*	LT01			ES52
		HR05			DEA3			LT02			ES53
		HR06			DEA4			NO01			ES61
		CZ01			DEA5			NO02			ES62
		CZ02			DEB1			NO03			ES63
		CZ03			DEB2	15	*Norway*	NO04			ES64
5	*Czech*	CZ04			DEB3			NO05			ES7
	Republic	CZ05			DEC			NO06			SE11
		CZ06			DED4			NO07			SE12
		CZ07			DED2			PL21			SE21
		CZ08			DED5			PL22			SE22
		DK01			DEE			PL41	22	*Sweden*	SE23
		DK02			DEF			PL42			SE31
6	*Denmark*	DK03			DEG			PL43			SE32
		DK04			EL3			PL51			SE33
		DK05			EL41			PL52			CH01
		FI19			EL42			PL61			CH02
		FI1B			EL43	16	*Poland*	PL62			CH03
7	*Finland*	FI1C			EL51			PL63	23	*Switzerland*	CH04
		FI1D			EL52			PL71			CH05
		FI2	10	*Greece*	EL53			PL72			CH06
		FR1			EL54			PL81			CH07
		FRB			EL61			PL82			NL11
		FRC			EL62			PL84			NL12
		FRD			EL63			PL91			NL13
		FRE			EL64			PL92			NL21
		FRF			EL65			PT11			NL22
		FRG			HU11			PT15	24	*The*	NL23
8	*France*	FRH			HU12			PT16		*Netherlands*	NL31
		FRI			HU21	17	*Portugal*	PT17			NL32
		FRJ			HU22			PT18			NL33
		FRK	11	*Hungary*	HU23			PT2			NL34
		FRL			HU31			PT3			NL41
		FRM			HU32			RO11			NL42
		FRY			HU33			RO12			UKC
		DE11			IE04			RO21			UKD
		DE12	12	*Ireland*	IE05			RO22			UKE
		DE13			IE06	18	*Romania*	RO31			UKF
		DE14			ITC1			RO32			UKG
		DE21			ITC2			RO41	25	*United*	UKH
9	*Germany*	DE22			ITC3			RO42		*Kingdom*	UKI
		DE23			ITC4			SK01			UKJ
		DE24	13	*Italy*	ITH1			SK02			UKK
		DE25			ITH2	19	*Slovakia*	SK03			UKL
		DE26			ITH3			SK04			UKM
		DE27			ITH4	20	*Slovenia*	SI03			UKN

Appendix III

Posthoc test pairwise comparisons of means with equal variances - Tukey

IC	Contrast	Std. Err.	t	P>t	[95% Conf. Interval]	
Position						
2 vs 1	0.543	0.053	10.25***	0.000	0.407	0.68
3 vs 1	0.957	0.080	11.89***	0.000	0.75	1.164
4 vs 1	1.297	0.082	15.76***	0.000	1.085	1.508
3 vs 2	0.413	0.08	5.19***	0.000	0.209	0.618
4 vs 2	0.753	0.081	9.25***	0.000	0.544	0.963
4 vs 3	0.34	0.101	3.35**	0.005	0.079	0.601
Participation						
2 vs 1	0.922	0.088	10.45***	0.000	0.695	1.148
3 vs 1	0.930	0.142	6.55***	0.000	0.565	1.295
4 vs 1	1.593	0.447	3.57**	0.002	0.445	2.741
Leadership						
2 vs 1	0.774	0.097	8.02***	0.000	0.525	1.022
3 vs 1	0.854	0.153	5.57***	0.000	0.46	1.248
4 vs 1	1.194	0.384	3.11*	0.010	0.207	2.181

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 5

Summary and conclusions

El artículo 18 del Acuerdo de 20 de diciembre de 2013, del Consejo de Gobierno de la Universidad de Zaragoza exige que, en caso de optar a la mención de "Doctor internacional", parte de la tesis doctoral sea redactada en una de las lenguas habituales para la comunicación científica en su campo de conocimiento, distinta a cualquiera de las lenguas oficiales en España.

La normativa impone la necesidad de incluir un resumen y conclusiones en castellano cuando la mayor parte de la tesis haya sido elaborada en inglés. En cumplimiento de la normativa aplicable, a continuación, se incluye un resumen y conclusiones en castellano.

1. Resumen de la tesis doctoral

El propósito de este capítulo es ofrecer una síntesis de la tesis doctoral, a la par que dar cuenta de sus principales conclusiones e implicaciones. Como se ha descrito en los capítulos anteriores, la presente tesis estudia la transferencia de conocimiento (KT) en a través de las redes de colaboración, así como explora su impacto en la capacidad de innovación desde una perspectiva macro, en un entorno cada vez más complejo.

La tesis se compone de cuatro capítulos, además de este resumen. El primero de ellos, *Capítulo 1*, tiene un propósito introductorio y su objetivo es contextualizar y presentar los diferentes objetivos de investigación, identificar las principales teorías empleadas y caracterizar el contexto en el que se van a llevar a cabo. Los tres capítulos restantes, *Capítulos 2, 3* y *4,* son los encargados de desarrollar los diferentes estudios que dan respuesta a los objetivos de investigación propuestos. Por un lado, el *Capítulo 2*, compuesto de dos estudios distintos, analiza la teoría que enmarca la presente tesis doctoral examinando los principales hallazgos, examinando la evolución de la disciplina e identificando futuras líneas de investigación. En el *Capítulo 3* se exploran los flujos de conocimiento en el contexto de la estrategia Horizonte 2020 (H2020), mientras que el *Capítulo 4,* trata de explicar el impacto de disponer de una determinada estructura de red sobre la capacidad innovadora de los sistemas regionales de innovación europeos y el papel mediador de la KT.

Resumen del Capítulo 1

El *Capítulo 1* constituye la introducción de la tesis doctoral. El conocimiento ha sido identificado como uno de los recursos intangibles de mayor valor en la generación de ventajas competitivas e innovación (Grant, 1996; Zhang & Zhang, 2018). Esto es especialmente relevante considerando que el paradigma económico y empresarial actual ha sido reconocido como una economía basada en el conocimiento (Powell et al., 2004), caracterizada por complejidad y dinamismo en los mercados. Como consecuencia de esto, el acceso a conocimiento externo para lograr resultados innovadores resulta vital. La literatura apunta que los nuevos sistemas de innovación se basan en las redes de colaboración ya que facilitan el intercambio de conocimiento (Boschma & Ter Wal, 2007; Gertler & Levitte, 2005; Owen-Smith & Powell, 2004). Sin embargo, sigue habiendo cuestiones sin resolver en la literatura que han tratado de ser abordadas en esta investigación.

A lo largo del capítulo introductorio se presenta el contexto teórico y empírico en el que se asienta la tesis doctoral. Con el fin de abordar el estudio de la KT y las redes, los capítulos de esta tesis hacen uso de tres corrientes de la literatura; la visión basada en conocimiento, la teoría de redes y los sistemas de innovación. Gracias a ello, esta investigación responde a cuestiones que continúan siendo debatidas en la literatura y ayuda a mejorar el conocimiento sobre este tópico. Con el propósito de examinar y testar empíricamente los objetivos de esta tesis, se acude a la estrategia H2020. La selección de esta estrategia viene justificada por su gran relevancia, por su presencia a nivel internacional y por su adecuación a los objetivos de los trabajos de investigación incorporados en esta tesis.

Resumen del Capítulo 2

El *Capítulo 2*, *Theoretical foundations*, incorpora dos estudios teóricos que sirven de punto de partida para los capítulos siguientes. El primer estudio, *The evolution of knowledge transfer and networks literature stream: A bibliometric approach*, identifica a los principales contribuyentes a la literatura de KT y redes, así como examina la evolución de la disciplina desde su origen hasta la actualidad.

En un mundo complejo en el que es inimaginable pensar en actores aislados, la KT se ha identificado como un proceso crucial para tener acceso a información, recursos y agentes externos (Cunningham & O'Reilly 2018; Easterby-Smith et al., 2008). De hecho, la KT ha sido considerada como uno de los principales determinantes del éxito empresarial (Tsai, 2001), quedando demostrado cómo una KT eficiente puede conducir a ventajas competitivas sostenibles (Zhang & Zhang, 2018). Cuando una empresa se convierte en miembro de una red de colaboración, tiene un acceso más fácil al conocimiento y en consecuencia, a recursos estratégicos a los que no podría acceder sin colaboración (Hemmert, 2019; Tallman & Chacar, 2011). Así, la red de colaboración es un concepto fuertemente vinculado a la KT (Aalbers et al., 2013; Cabrera-Suárez et al., 2018).

La KT tiene sus raíces en la literatura de la gestión del conocimiento, cuyos orígenes se remontan a los años 60 (Gaviria-Marín et al., 2019). Sin embargo, no fue hasta el año 2000 cuando se definió el concepto de KT (Argote & Ingram, 2000). A pesar de ser una disciplina joven, el estudio de la KT y las redes ha atraído la atención de investigadores y profesionales por su potencial influencia en la toma de decisiones estratégicas a nivel empresarial y político. Al tratarse de un área todavía incipiente, aunque la mayor parte de la atención procede del estudio de la gestión empresarial, investigadores han tratado de abordarla desde múltiples perspectivas, generando cierto de desorden académico. Por otra parte, los métodos bibliométricos suscitan un interés científico cada vez mayor porque permiten explorar de forma objetiva y cuantitativa el estado del arte de una disciplina a partir de grandes muestras bibliográficas (Xu et al., 2021). Aunque la gestión de conocimiento ha sido estudiada por técnicas bibliométricas (Gaviria-Marin et al., 2019), el tópico específico de la KT y las redes no ha sido examinado hasta la fecha.

En consecuencia, nuestra intención con este estudio es desarrollar un análisis bibliométrico sobre KT y redes con el objetivo de alcanzar una mejor comprensión de la disciplina. Este objetivo general se concreta en tres preguntas de investigación que son respondidas a lo largo del trabajo: RQ1. *¿Quiénes son los contribuyentes más influyentes en este campo?* RQ2. *¿Cómo ha evolucionado la disciplina?* RQ3. *¿Cuáles son las principales áreas de investigación emergentes y cuáles son las principales vías de investigación futuras?* Para ello, en este trabajo se emplean los dos métodos básicos de la bibliometría (Noyons et al., 1999); el análisis de la productividad y el mapeo científico, y hace uso de técnicas adicionales como el análisis de redes complejas para enriquecer los resultados (Donthu et al., 2021).

Este estudio ofrece una visión global y rigurosa de los últimos 20 años de la KT y las redes. Se revela que, en primer lugar, es un área de investigación que está ganando atención en los últimos años y en segundo lugar, el análisis de redes permite interpretar la evolución del campo a través de la evolución de las palabras clave más importantes y su interrelación. En este sentido, el área ha evolucionado desde un nivel estratégico y corporativo a uno dinámico e institucional. Es decir, el interés de la investigación en KT ha evolucionado desde una perspectiva teórica, micro y estructural a una perspectiva práctica, macro y compleja.

El segundo estudio, *Deepening the understanding of knowledge transfer and networks' foundations: Future research lines and challenges,* profundiza en las principales contribuciones teóricas del tópico de la tesis doctoral.

Aunque, tal y como se veía en el estudio anterior, el concepto de KT ha sido objeto de debate durante las últimas décadas, ha sido en los últimos años cuando la academia se ha centrado en esta cuestión. Los investigadores han tratado de dar respuesta a preguntas como: ¿Cuáles son los antecedentes que determinan una mayor y mejor propensión a transferir conocimiento (Kaminski et al., 2008; Levin & Walter, 2019)? ¿Qué consecuencias en términos de rendimiento innovador aporta la KT (Mariotti, 2011; Villasalero, 2013)? ¿Cómo afectan los diferentes ecosistemas y contextos a la voluntad de generar redes de KT (Frenz & Ietto-Gillies, 2009)?

La literatura ha demostrado que los determinantes y los efectos no son los mismos para todos los procesos de KT. En concreto, se ha examinado la KT tanto en redes intraorganizativas (Kim et al., 2014), es decir, entre unidades de la misma empresa, como en redes interorganizativas (Maggioni et al., 2011), es decir, entre diferentes organizaciones. Las empresas multinacionales han recibido gran atención dado el interés por analizar los flujos de conocimiento entre las filiales y la sede central (Claver-Cortés et al., 2018; Nadayama, 2019). La literatura también ha revelado la importancia de promover las relaciones con organizaciones que crean conocimiento como las universidades (Chen et al., 2019), y con instituciones que facilitan los procesos de aprendizaje y que actúan en forma de bancos de conocimiento, como los poderes públicos (von Malmborg, 2004).

Para ofrecer una visión global de la literatura, se realiza una revisión sistemática utilizando las bases de datos Web of Science y Scopus con el objetivo de identificar las publicaciones más relevantes en un periodo de 20 años. Para garantizar la calidad de la muestra seleccionada, se incluyeron criterios de filtrado objetivos que permitió analizar una muestra de 190 estudios de investigación de alto impacto.

Este estudio pretende contribuir a la literatura respondiendo a estas preguntas (1) *¿Cuáles son las principales conclusiones conceptuales de los estudios centrados en el análisis de la KT y las redes de colaboración?* (2) *¿Qué dice la literatura sobre los antecedentes, los determinantes y los efectos de la KT en la innovación y, por tanto, en el rendimiento empresarial?* (3) *¿Qué papel desempeñan los distintos contextos e instituciones en los procesos de difusión del conocimiento?* y (4) *¿Cuáles son los principales gaps y próximas tendencias de investigación?*

En primer lugar, la literatura ha confirmado que la posición de un determinado agente en un ecosistema de colaboración representa un factor esencial para lograr flujos de KT eficientes y eficaces (Chen & Hung, 2010). En segundo lugar, la absorción e integración del conocimiento externo depende en gran medida de la estructura de la red de colaboración en la que se encuentran los agentes (Aalbers et al., 2013; Cabrera-Suarez et al., 2018; Uzzi & Lancaster, 2003; Wang, 2013). En otras palabras, una posición estratégica más central permite la generación de relaciones de colaboración y en consecuencia, de potenciales vías de KT.

Las conclusiones de este estudio también se organizan en función de los tipos de agentes que componen las relaciones de KT. Dadas sus características inherentes, las empresas multinacionales han recibido más atención. Otras investigaciones han analizado la KT entre universidades e industrias. Las universidades y los centros de investigación, por su papel de generadores de conocimiento, representan agentes esenciales en el sistema de innovación (Hewitt-Dundas, 2012; Seibert et al., 2017). En este sentido, la identificación de las barreras que dificultan la KT entre los generadores de conocimiento y la industria han sido especialmente abordadas en la literatura (Fischer et al., 2020; Spithoven et al., 2021). Los autores convergen en una idea principal: la necesidad de crear mecanismos que faciliten las prácticas de KT para hacer frente a las dificultades detectadas. Por último, las instituciones públicas también desempeñan un papel intermediario fundamental en la consecución de redes de aprendizaje colaborativo (von Malmborg, 2004). Esta revisión también ha resumido algunas de las recomendaciones que fomentan el desarrollo de los procesos de KT y, a largo plazo, la creación de valor regional. En este sentido, los incentivos que estimulan los flujos de conocimiento, así como la creación de una agenda de conocimiento, pueden proporcionar una hoja de ruta que mejore los ecosistemas de innovación.

Resumen del Capítulo 3

El *Capítulo 3*, *Exploring knowledge transfer ecosystems*, presenta un estudio exploratorio titulado *The European research landscape under the Horizon 2020 Lenses*, que examina los flujos de KT en Europa bajo la óptica de la estrategia H2020. Este trabajo profundiza en el entendimiento de los impulsores de la innovación para las PYMEs analizando tres perspectivas diferentes: a nivel país, a nivel agregado de acuerdo al modelo Triple Hélice (TH) y a nivel desagregado y organizativo.

La generación y transferencia de conocimiento, tanto entre como dentro de las organizaciones, son procesos fundamentales en el desarrollo de actividades de I+D (Cunningham & O'Reilly 2018; Easterby-Smith et al., 2008), que suelen derivar en nuevos productos o procesos a través de la innovación. Sin embargo, las PYMEs, debido a su falta de recursos tangibles e intangibles suficientes, a menudo ven frustrados sus esfuerzos por llevar a cabo la innovación de forma individual (Brunswicker &

Vanhaverbeke, 2015). En consecuencia, se ven obligadas a abandonar estas actividades o, como alternativa, a participar en redes de colaboración. Sin embargo, la literatura no explora esta cuestión desde una perspectiva lo suficientemente holística. En este contexto, el modelo de la TH, que reconoce explícitamente la relevancia de las interconexiones entre las empresas, las instituciones públicas y los centros de investigación y universidades (Etzkowitz & Leydersdoff, 1995), es una herramienta adecuada para entender las relaciones entre los distintos agentes que permitirá, en una fase posterior, sentar las bases para visibilizar y fomentar las actividades innovadoras entre empresas.

Estudios recientes han fomentado el análisis específico de las redes empresariales con el fin de examinar contextos complejos (Hervás et al., 2021 Tsouri y Pegoretti, 2021; Tsai 2001). Sorprendentemente, hay poca investigación transnacional hasta la fecha que visualice las colaboraciones existentes que impulsan la innovación en las PYMEs basadas en los agentes del modelo TH. Con este argumento en mente, este estudio trata de mejorar la comprensión de las complejas relaciones que se desarrollan en el ecosistema europeo. En particular, se trata de responder cuestiones como la forma en que la investigación sobre la innovación en PYMEs se canaliza a través de las redes y qué países europeos lideran los proyectos de innovación en PYMEs.

Este trabajo presenta dos objetivos de investigación: (1) *Evaluar el panorama de investigación en Europa que promueve la innovación en las PYMEs a través del análisis de la financiación de la estrategia H2020*, y (2) *Explorar la posición de cada uno de los agentes que componen el modelo TH en su papel de sujetos activos en la investigación sobre innovación en las PYMEs*. Para lograr estos objetivos, se adopta la metodología de análisis de redes con el fin de visualizar el panorama europeo en materia de investigación sobre innovación en las PYMEs. Para ello, se hace uso de información proveniente de la estrategia H2020 y se consideran todos los proyectos de investigación financiados de la categoría *Innovation in SMEs*. Este proceso de búsqueda permitió analizar 1.055 proyectos que fueron financiados entre 2014 y 2019, distribuidos entre 971 empresas privadas, 399 instituciones públicas y 213 grandes centros científicos (BSC).

Se emplea el análisis de redes para valorar la relevancia de los principales actores (nodos) del proceso, así como el éxito de las interacciones. Se introduce el concepto de centralidad, tomado de la física y la informática, y se calculan cuatro tipos de centralidad (centralidad de grado, centralidad de interrelación, centralidad de vectores propios y centralidad de proximidad) para evaluar la conectividad y relevancia de cada agente.

Se muestra que no existe una relación clara y directa entre la financiación recibida de H2020 y el posicionamiento estratégico en términos de conectividad, o la relevancia económica del país. En este sentido, Alemania, España e Italia representan los países con mayor poder de colaboración y conectividad de toda la red. Por tanto, estos países, que muestran valores más altos de centralidad, pueden considerarse nodos interesantes a tener en cuenta para futuras redes de colaboración. También se concluye que mientras las empresas del sector privado obtienen, generalmente, la mayor cuantía de fondos para realizar actividades innovadoras, su importancia relativa es menor cuando se refiere a la KT con otros agentes. En este sentido, los BSC a pesar de no recibir la misma cuantía económica, están mejor posicionados en términos de centralidad en la red europea. Esto permite concluir que los BSC pueden ser considerados impulsores clave de la innovación para las PYMEs en Europa.

Esta investigación muestra que las partes más cohesionadas de Europa se corresponden con el "viejo continente". Esto significa que la mayor densidad de colaboración se establece entre los países del corazón del continente y que la red entre estos países será más difícil de romper. Sin embargo, también hay países que no pertenecen a este grupo y que han conseguido excelentes resultados en estos programas.

Algunos ejemplos son España, Armenia, Portugal, Serbia y Croacia. Los países menos centralizados, generalmente de menor tamaño, pueden identificar a los países grandes y más cohesionados como barreras y a menudo pueden tener dificultades para generar posibles colaboraciones, con la consecuencia no deseada de que se pierdan proyectos de investigación potencialmente valiosos que provienen de estos países periféricos. La amenaza más peligrosa que se deriva de estos resultados está asociada a los sentimientos de frustración y desmotivación de las empresas que no pertenecen a esta red de colaboración. Además, la alta competitividad de los países con características similares (alta centralidad y capacidad de innovación) también puede ser entendida como una amenaza por las otras regiones. Los países pequeños deberán ser capaces de desarrollar políticas de actuación, identificarlas e intentar mejorar sus resultados. De este modo, podrán identificar socios y unirse a la red europea de investigación para buscar el equilibrio y la simetría óptimos de la red.

Una cuestión que queda fuera del alcance de este trabajo tiene que ver con quién debe encargarse de estas actividades innovadoras. En un mundo globalizado, se puede argumentar que la mejora del bienestar social europeo es incluso más importante que el origen de los países que contribuyen a ello. También hay que tener en cuenta que el hecho de que un país o una institución no reciba financiación en sus primeras colaboraciones en proyectos de H2020 no debe tomarse necesariamente como algo malo en la medida en que el establecimiento de relaciones con otros países e instituciones hará que estos países tomen una posición de liderazgo en futuros proyectos y aumenten la financiación obtenida, logrando efectos de aprendizaje. En este contexto, debemos prestar especial atención a la centralidad y cohesión de la red desarrollada, ya que estos indicadores proporcionan una valiosa información sobre los resultados futuros esperados. En este sentido, entendemos que H2020 es una poderosa herramienta en el fortalecimiento de la red de investigación colaborativa europea.

Resumen del Capítulo 4

El *Capítulo 4*, titulado *Do collaboration structures matter in regional innovation systems?* ofrece continuidad a los capítulos anteriores, analizando empírica y causalmente el impacto de la estructura de la red de conocimiento en la capacidad de innovación regional europea, contemplando a su vez, el papel mediador de la KT.

Uno de los principales campos de investigación actuales en la literatura de la innovación es el entendimiento de los flujos de colaboración. Este especial interés proviene de la evolución de las estrategias de innovación (Chen et al., 2019). Hasta hace poco, Europa se basaba en la idea de que la innovación debía conseguirse simplemente aumentando la inversión en I+D del PIB de forma generalizada (Hervás-Oliver et al., 2021). Pero este enfoque ha sido criticado tanto por la academia como por la industria y responsables políticos, ya que no tiene en cuenta las especificidades del contexto de las regiones en las que operan las empresas (Cooke & Morgan, 1994; Cooke, 2001). Hoy en día, la innovación es cada vez más colaborativa y el nivel de innovación viene determinado, en cierta medida, por la estructura del ecosistema (Parrilli et al., 2020). De este modo, la comprensión de este nuevo entorno para la innovación está atrayendo la atención de la academia.

Sin embargo, el estudio de este nuevo entorno es complejo porque tal y como se deriva de las conclusiones del capítulo anterior, en primer lugar, los límites de las industrias ya no están definidos, en segundo lugar, el ecosistema es dinámico, por lo que cambia constantemente de forma muy rápida y, en tercer lugar, cada vez hay más actores interactuando en él. Esta complejidad ha llevado a intentar comprender cómo se establecen las relaciones y cómo se transfieren los recursos y las capacidades para aumentar el rendimiento de la innovación teniendo en cuenta las especificidades regionales (Cooke, 1992). Esta idea de colaboración para lograr la innovación aboga por que las redes son necesarias para crear relaciones y permitir la generación de flujos que al final conducirán a la innovación (Boschma & Ter Wal, 2007; Gertler & Levitte, 2005).

Nuestro punto de partida es considerar que, siguiendo la visión basada en el conocimiento (Grant, 1996; Inkpen & Tsang, 2016), el conocimiento es uno de los activos intangibles más relevantes capaces de generar innovación (Tsai, 2001). En un ecosistema complejo, tener acceso a fuentes de conocimiento externas es crucial para poder responder a las presiones del mercado y de la sociedad (Zou & Ghauri, 2008). Teniendo esto en cuenta, las redes pueden actuar como estructuras facilitadoras de los flujos de conocimiento externo entre los actores integrados en ellas. Así, la literatura anterior ha señalado que las redes de conocimiento constituyen un elemento indispensable del proceso de innovación gracias a su papel como puentes de conocimiento (Khan et al., 2015).

Las contribuciones empíricas en este ámbito toman en consideración conceptos relevantes vinculados al estudio de las redes como el incrustamiento de los actores a la red de conocimiento (Vicente et al., 2011), o la proximidad de los actores (Boschma & Ter Wal, 2007) como características de las redes de conocimiento que estimulan el intercambio de conocimiento. En estos estudios, los autores señalan que la posición que ocupa el agente en una red es crucial para el rendimiento de la innovación porque determina el acceso al conocimiento externo (Villasalero, 2013). Otros estudios han tratado de examinar cómo influye el liderazgo en la innovación a través de la colaboración y han descubierto la importancia de que el líder estimule la creación de relaciones (Szatmari et al., 2021). Además, otros investigadores han llegado a la conclusión de que los agentes más participativos en las redes dispondrán de mayor probabilidad de obtener recursos del exterior y, en consecuencia, esto puede repercutir en el rendimiento innovador (Tsouri & Pagoretti, 2021).

A pesar del creciente interés en esta corriente de la literatura, la mayor parte de las investigaciones han examinado la estructura de las redes en contextos específicos (Buchmann & Kaiser, 2019; Tsouri & Pagoretti, 2021), lo que lleva a pasar por alto en cierta medida la complejidad de los sistemas de innovación. En particular, la dimensión geográfica de fenómenos como las colaboraciones es de especial interés para comprender la difusión espacial del conocimiento, ya que tiene implicaciones políticas relevantes (Scherngell & Barber, 2011). En realidad, estudios anteriores, así como conclusiones de los capítulos anteriores de esta tesis doctoral, reclaman más investigaciones que analicen las complejidades de la innovación en entornos internacionales desde una perspectiva dinámica y estructural (Volberda et al., 2014), ya que las redes de conocimiento se consideran componentes esenciales de los sistemas de innovación (Doloreux & Parto, 2005; Höglund & Linton, 2018).

En este trabajo se profundiza en esta idea, así como en la comprensión del efecto de la estructura de las redes de conocimiento en la capacidad innovadora regional. Se analiza cómo la posición, el papel del liderazgo y la participación activa influyen en los sistemas regionales de innovación. Este estudio sostiene que la capacidad de innovación regional depende de un complejo conjunto de variables de redes de colaboración que, en no poca medida, son contingentes a los lugares donde se ubican los agentes y que, por tanto, determinarán la capacidad de innovar. También se estudia el papel de la KT a través de las redes. Se entiende que disponer de capacidad de KT reforzará la capacidad innovadora actuando como factor mediador en el modelo propuesto, tal y como han señalado estudios anteriormente (Maurer et al., 2011).

Por tanto, este estudio trata de dar respuesta al siguiente objetivo de investigación: *analizar hasta qué punto la estructura particular de una red de conocimiento que depende principalmente de la colaboración conduce a una mayor capacidad de innovación regional y cuál es el papel de la KT en esta relación*. Se pretende comprender los impulsores de la capacidad de innovación en las regiones europeas, evaluando cómo influyen las características estructurales de una red.

Se realiza un estudio empírico haciendo uso de proyectos de colaboración europeos (H2020) de 2014 a 2020. Se analizan 8.424 proyectos en los que han participado 14.608 empresas de 232 regiones europeas (NUTS2). Esta base de datos es especialmente útil para los fines de este trabajo por varias razones. En primer lugar, proporciona información de un ecosistema complejo que involucra a diferentes actores, países e industrias. En segundo lugar, proporciona información longitudinal que permite garantizar robustez en los resultados. Por último, es original, permitiendo estudiar un entorno único no explorado hasta ahora desde una perspectiva macro con incorporando el componente dinámico.

Este estudio ha tratado de comprender mejor el efecto de la estructura de las redes de colaboración sobre la capacidad de innovación regional en Europa. Se ha tratado de determinar si, efectivamente, tres de las variables más relevantes en el estudio de la estructura de las redes complejas sirven como impulsoras en los sistemas regionales de innovación y cómo varían según sus niveles y características de la región. Además, se ha estudiado qué papel juega la KT, hasta qué punto canalizan el conocimiento y si repercuten en la capacidad innovadora de las regiones.

Para ello, se ha respondido a tres preguntas de investigación. En primer lugar, se ha evaluado hasta qué punto la capacidad de innovación de los sistemas regionales se explica por la estructura que estas regiones ocupan en la red europea de conocimiento. En segundo lugar, se ha comprobado la importancia de contar con capacidad de KT para la generación de innovación. En tercer lugar, se ha profundizado en el entendimiento de estas relaciones en el contexto de la estrategia H2020, pretendiendo ofrecer un estudio que sirva como herramienta para de evaluación de las políticas de innovación europeas. En resumen, este estudio arroja luz sobre la importancia de la colaboración como motor de la innovación regional y la importancia de las redes y su estructura en la KT.

Los resultados indican que, en Europa, la capacidad de innovación regional está impulsada en parte por la colaboración entre los agentes de la red de conocimiento. Queda claro, por tanto, contribuyendo a la literatura de los sistemas de innovación, que se está produciendo una evolución con respecto a las políticas de innovación europeas. Ya no sólo es importante invertir en I+D interna, sino que es crucial fortalecer las relaciones entre los agentes que conforman el ecosistema. En este sentido, se aportan pruebas sólidas. Estudios anteriores ya apuntaban a estas conclusiones, indicando que el énfasis en la I+D como principal insumo en el proceso de innovación ha demostrado estar lejos de ser la mejor manera de avanzar en la innovación, especialmente para las regiones menos innovadoras (Hervás-Oliver et al., 2021) que probablemente tengan estructuras organizativas y recursos más limitados.

Este trabajo aporta evidencias que, en línea con lo encontrado para contextos específicos (Tsouri & Pegoretti, 2021), indican que tener una posición central respecto al resto de los agentes que componen la red influye en la capacidad innovadora regional. Esto refuerza la idea de la importancia de posicionarse en el lugar adecuado y con los agentes del sistema de innovación de mayor interés. En segundo lugar, se concluye que una mayor participación activa en la red de conocimiento ayuda a desarrollar la capacidad de innovación de los sistemas regionales. En otras palabras, la innovación se nutre del conocimiento, y aunque a priori la participación en un proyecto de investigación no tenga un retorno económico, sólo participando se puede acceder a un conocimiento que de otro modo no sería posible por estar fuera de los límites regionales. En tercer lugar, se aportan evidencias de que ocupar una posición de liderazgo (o de coordinación) en una red de conocimiento tiene un impacto en la capacidad innovadora regional. Es decir, las regiones que desempeñan un papel de liderazgo en la red son las que más se benefician en cuanto a su capacidad de innovación. La explicación se encuentra en la función de centralización del conocimiento de los líderes de proyectos de investigación. Entre otras funciones, un coordinador de proyecto centraliza y organiza la información y los recursos, lo que puede ayudar a generar relaciones de mayor confianza y a adquirir y absorber conocimientos, incluso en forma de *spillovers*, contribuyendo así a desarrollar la capacidad de innovación del territorio.

Se insiste en la necesidad de desarrollar políticas que enfaticen la colaboración entre regiones y el papel de los ecosistemas locales. Por ello, las políticas de innovación, tanto a nivel nacional como europeo, deberían tratar de fomentar, por un lado, la participación en redes de colaboración, en segundo lugar, generar incentivos para que las regiones menos innovadoras ocupen también posiciones de coordinación, y por último, con el objetivo de generar relaciones estratégicamente atractivas con otros agentes de la red, sería interesante generar un sistema de mapeo colaborativo que permitiera contactar con determinados agentes de la red según objetivos particulares.

Los resultados de este capítulo también sugieren que no sólo es importante tener una estructura de red adecuada, sino que las redes actúan como un canal a través del cual se transfiere el conocimiento. En este sentido, las regiones con mayor capacidad de KT encuentran que su capacidad de innovación es mayor. Esta conclusión permite entender la innovación como un proceso, lo que implica que, en primer lugar, es importante conseguir una situación adecuada en el ecosistema, y en segundo lugar, es fundamental poder transferir el conocimiento y poder absorberlo, para finalmente desarrollar la capacidad innovadora.

2. Implicaciones prácticas

La tesis doctoral presenta resultados que contribuyen de forma relevante a la literatura sobre la visión basada en el conocimiento, la teoría de redes y los sistemas de innovación. Más allá de las contribuciones a la literatura académica, los resultados son relevantes para el mundo profesional. La tesis presenta implicaciones prácticas que podrían dividirse en dos secciones, implicaciones para gerentes e implicaciones para poderes públicos.

Implicaciones para gerentes

Existe un amplio acuerdo sobre los beneficios que la creación y difusión de conocimientos aportan, en primer lugar, al comportamiento innovador y, en segundo lugar, a los resultados económicos. En el *Capítulo 2* se ha mostrado como el papel del conocimiento es importante en la creación de valor y debe articularse dinámicamente con la estrategia empresarial. Esto significa que los cambios en la estrategia de una organización implican ajustes en la estrategia de gestión y en la KT. En este sentido, se ha hablado de la gestión del conocimiento y, por tanto, de la KT como un tipo específico de proceso subyacente a las capacidades dinámicas que se basa en la experimentación y en la identificación de nuevas oportunidades que contribuyen a la reconfiguración de los recursos y las rutinas operativas. Este proceso requiere una combinación dinámica adecuada de relaciones sociales, prácticas de gestión y herramientas técnicas que tiene un efecto significativo en el rendimiento empresarial.

Los profesionales deben ser conscientes de ello. A lo largo de la tesis se han presentado múltiples argumentos a favor de la implantación de mecanismos de facilitación de la KT en las empresas. Disponer de una cartera dinámica de conocimientos empresariales almacenados puede ayudar a identificar los puntos débiles y fuertes de la empresa. Esto puede permitir el desarrollo de planes de acción estratégicos en torno a la creación de redes de innovación colaborativa. Algunos de los determinantes más importantes de los procesos de KT eficaces están relacionados con el capital social. En este sentido, los sistemas de gestión del conocimiento son el punto de partida, ya que permiten la creación de espacios en los que los socios pueden compartir información y conocimiento a través de plataformas comunes. La tecnología por sí sola es necesaria para su aplicación, pero no es suficiente para aumentar la capacidad de innovación. Las empresas tienen que reforzar su propensión a colaborar seleccionando a los socios adecuados y estableciendo la intensidad de las relaciones. Los profesionales que pretendan implantar mecanismos de KT en sus organizaciones a través de sistemas de gestión de conocimiento deben prestar más atención a la forma en que los procesos de conocimiento pueden afectar al rendimiento, considerando la dinámica y la interconexión de los procesos. Los sistemas de gestión del conocimiento sirven como medio para combinar la exploración y la explotación con el fin de superar las dificultades de integrar diferentes modos de aprendizaje.

En este sentido, se sugieren cuatro etapas para la implantación de sistemas dinámicos de gestión del conocimiento. En primer lugar, la evaluación del estado actual de las estrategias de gestión del conocimiento. Segundo, la identificación de metas y objetivos mediante el establecimiento de un inventario de los recursos y capacidades disponibles y la participación del liderazgo. En tercer lugar, el desarrollo de una estrategia de gestión del cambio mediante la determinación de sus procesos y la elaboración de una hoja de ruta de implantación. Por último, una vez implantado el sistema, evaluar periódicamente su eficacia y realizar mejoras continuas.

El *Capítulo 3* converge en las implicaciones anteriores, ya que, desde el punto de vista de la toma de decisiones, los directivos deben ser conscientes de los efectos indirectos positivos que se derivan de la colaboración. En este sentido, las universidades y otros centros científicos desempeñan un papel fundamental en este proceso y deben ser considerados como socios cuya colaboración será beneficiosa para ambas partes. Del mismo modo, los proyectos conjuntos de I+D con otras empresas también pueden reforzar la posición competitiva de las empresas.

Por último, esta tesis doctoral pretende ser utilizada como una herramienta estratégica de evaluación de estrategias de innovación a través de la visualización de interacciones entre las organizaciones de la red de conocimiento. Además, ofrece potencial de predicción de relaciones valiosas con el objetivo de mejorar y transferencia de recursos entre empresas. También, en línea con las conclusiones del *Capítulo 4*, permite identificar si existen flujos de KT, en qué áreas y en qué nivel, lo cual puede ayudar a trazar estrategias empresariales alineadas con las políticas regionales para mejorar el desarrollo territorial.

Implicaciones para poderes públicos

Por último, y en relación con las implicaciones para los poderes públicos, esta tesis doctoral evidencia cómo dar visibilidad pública a los procesos de KT y colaboración existente a nivel regional o internacional permitirá crear culturas colaborativas de innovación. En este sentido, la creación de observatorios de transferencia a nivel macro que permitan el registro longitudinal de las actividades de transferencia y, en última instancia, la creación de indicadores clave de rendimiento, puede ayudar a profesionales y otras partes interesadas a conocer y participar en actividades de colaboración con socios estratégicos.

El *Capítulo 2* sugiere que las autoridades deben conocer el panorama del sistema de innovación en sus regiones o países. Poner esta información a disposición de otros agentes del ecosistema puede permitir el desarrollo de acciones para mejorar los procesos de KT y fortalecer las redes de colaboración. Además, se ha mostrado cómo la interacción entre los centros generadores de conocimiento y las empresas es vital para la consecución de la innovación y la contribución en el crecimiento regional. Las autoridades deberán proporcionar los recursos necesarios y los mecanismos flexibles para la comercialización del conocimiento. Sólo así se pueden crear redes de colaboración KT fuertes y estables. Por último, se ha puesto de manifiesto como la creación de una cultura colaborativa de confianza es fundamental. Los responsables políticos pueden contribuir a atraer a los agentes externos dando visibilidad al conocimiento creado en una determinada región o sector. En consecuencia, ofrecer una imagen innovadora y transparente puede promover la colaboración en KT entre los agentes, así como atraer a agentes externos y fortalecer la cultura de confianza colaborativa.

Por otro lado, el uso de las redes complejas como se emplean en el *Capítulo 3*, permiten identificar algunos de los puntos fuertes y débiles del sistema de innovación de un área geográfica. La información proporcionada por los indicadores de centralidad es valiosa para realizar un análisis detallado que se centre en empresas, industrias o países específicos con el objetivo de orientar las decisiones políticas. Una vez se conocen qué países o qué empresas lideran el panorama de I+D en un área determinada, es más fácil desarrollar las acciones adecuadas que faciliten la propia competitividad de una empresa o identificar las industrias que pueden alcanzar posiciones centrales en las redes.

Una cuestión que no puede olvidarse es que las universidades y los centros de investigación han sido identificados en esta tesis como motores de la innovación en Europa. En consecuencia, es importante que desde una perspectiva institucional se les proporcione los recursos necesarios para reforzar su interacción con las PYME en la medida en que estas redes tendrán efectos positivos en los resultados de las empresas, y consecuentemente de la sociedad. El conocimiento que reside en las universidades y centros de investigación es un activo potencial valioso, así que los responsables políticos deberán encargarse de establecer mecanismos que garanticen la eficacia de esta KT.

La posición secundaria de las instituciones gubernamentales en la red lleva a pensar que no hay suficiente conciencia de las características y problemas específicos de las empresas. Las autoridades deben tomar conciencia del papel de palanca que pueden desempeñar al adoptar un papel activo en el ecosistema de I+D. Hay varias dimensiones que podrían considerarse para lograr una red más cohesionada: los conflictos de intereses entre las partes que emprenden la cooperación, la falta de recursos tanto en el ámbito privado como en el de los centros de investigación y las universidades, y los obstáculos burocráticos relacionados con los mecanismos necesarios para acceder a los fondos estructurales.

Además, a nivel europeo, esta información puede ser útil para la formulación de una hoja de ruta para la continuación de la estrategia Horizonte Europa que favorezca la consecución de determinados objetivos. A modo de ejemplo, la Unión Europea debería decidir si prefiere reforzar la posición de los consorcios europeos más importantes para que puedan competir con los principales líderes americanos y asiáticos, a costa de limitar el desarrollo de otras empresas, o si opta por un apoyo más horizontal y menos focalizado que permita el desarrollo de un mayor número de empresas. O quizás sea mejor lanzar programas diferenciados que den un tratamiento distinto a cada una de las dos tipologías mencionadas.

Por último, el *Capítulo 4*, ofrece importantes implicaciones para poderes públicos. Al diseñar las políticas de innovación, los responsables locales deben tener en cuenta el comportamiento estratégico de los actores en el proceso de KT dentro de la red. Dado que los actores más centrales son los más beneficiados en términos de innovación, es probable que las políticas de colaboración refuercen su dominio en la red, frenando la aparición de actores locales periféricos y nuevos participantes. Consideramos que, la política de innovación podría ser aún más eficaz si se dirige a subredes equilibradas, con el fin de reforzar la posición de los actores locales periféricos en el sistema, incluyéndolos en el proceso de innovación. Esto haría que estos actores periféricos locales fueran más atractivos para futuras colaboraciones con los nuevos participantes, fortaleciendo toda la red de conocimiento y facilitando la KT. Así pues, este último estudio destaca el papel de las redes de colaboración como fuente de innovación regional y la importancia de la KT en esta relación. Puede considerarse especialmente relevante para el diseño de futuras políticas regionales europeas o para afrontar los retos globales sobrevenidos.

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