Networks and innovation: enhancing the knowledge through a bibliometric network analysis

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Abstract: The relationship between networks and innovation has become a prominent research area due to the high popularity of network theories and methods to determine the drivers of innovation. However, little consensus on the understanding of networks and sources of innovation has been achieved. To evaluate the current state of the research, we perform a bibliometric analysis of the scientific production of networks and innovation published in journals listed in Scopus. First, we show the characteristics of scientific production: the main disciplines working in the field, the evolution over time, the contributing countries, the international collaborations, and the most cited and referenced publications. Second, through keyword co-occurrence, co-citation, and bibliographic coupling analyses, we pinpoint whether this apparently heterogeneous research area is based on a common or different schools of thought. This is the first comprehensive study offering a general overview of the leading trends in the scientific production of networks and innovation.

Keywords: network analysis; social capital; networking; innovation; bibliometrics.

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1 Introduction

Since the 1990s, modern views on innovation tend to consider that innovation is an interactive process in which social relationships play a crucial role (Lundvall, 1992). Networks – consisting of relationships between individuals, groups, organisations, or other social units – can adopt forms that facilitate or inhibit social action (Granovetter, 1985). Innovations have been framed as novel combinations of knowledge that produce different forms of value (Borrás and Edquist, 2019; Henderson and Clark, 1990). Because networks are conduits of information and knowledge, and because innovation is one of the major elements of competitiveness among organisations in modern societies, the relationship between networks and innovation has been a background hypothesis that has propelled the emergence of a whole new area of scholarly research.

Innovation is a major component of research on networks, and networks have become a paradigm through which to study innovation by considering several mechanisms (Vedres, 2022). An important research stream has focused on networks as a way to access non-redundant information that is difficult to obtain in the absence of specific relationships (Ahuja, 2000). Other studies have concentrated on the advantages created by networks to provide trust in collective enterprises, resulting in knowledge sharing and collaborative work (Tsai and Ghoshal, 1998). Still others have documented how the conditions created by networks facilitate the learning of useful knowledge and abilities (Powell et al., 1996), often resulting in more robust knowledge that enables competitive advantages (Ferrary and Granovetter, 2017).

The study of the relationships between different forms of networks and innovation has become a multipurpose and multidisciplinary research domain. It has attracted the interest of diverse problem areas, including business, education, urban planning, economic development, and the environment. Studies on networks and innovation spread throughout several disciplines, including management, sociology, psychology, geography, economics, and engineering. A huge amount of research literature has

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emerged. There are more than 24,000 published peer-reviewed articles on this topic indexed in Scopus, in addition to many books and other types of scholarly writings. Because of the large number of topics, approaches, and participating actors and institutions in this broad research area, the field is difficult to map, making single statements difficult to sustain.

There are several barriers to making the state of knowledge explicit and systematic. First, little consensus exists on the concepts, types, and levels of analysis of networks. Networks have been theorised in several ways: as a social structure, as collective or individual social capital, or as a course of action (Burt, 2004; Nahapiet and Ghoshal, 1998; Pittaway et al., 2004). To analyse innovation processes, research has analysed various network types, such as personal networks, interorganisational networks, intrafirm networks, and knowledge networks. Moreover, studies have performed different levels of analysis – at the actor level, the dyadic level, and the network level – and in different settings, such as informal groups, organisations, fields, and territorial units.

Second, studies have used different outlooks to study innovation. Some streams of research focus on the production of innovation, others focus on the adoption of innovations, and still others focus on the spread of ideas and knowledge (Fagerberg et al., 2012; Martin, 2019). Some perspectives use a narrow view of innovation, identifying innovation implicitly with technological innovation in close connection to science, while others apply a broader view to several types of organisations and to different sectors of societies. Finally, within this research area, there are substantive debates that make arguments in opposite directions. A consolidated line of inquiry sees weak ties as a source of innovation (Burt, 2004), whereas a rival perspective concludes that strong ties facilitate innovation (Rost, 2011; Ruef, 2002).

To evaluate the broad and heterogeneous current research, it is necessary to consider different insights, cover multiple disciplines, and include literature from different timeframes because both networks and innovation are multilevel, interdisciplinary and multidimensional constructs. Previous review studies have concentrated on a specific area, such as small and medium-sized companies (Toigo, 2017), have considered only one type of network (interorganisational networks) (Dagnino et al., 2015), or have focused on a single network approach, such as networking (Pittaway et al., 2004). Other reviews have associated innovation with specific economic dynamics, such as new market growth (Müller and Peres, 2019). Given the risk of focusing such reviews on a biased selection of topics, levels of analysis, or settings, we turn to bibliometrics, which offers an opportunity to map the content and structure of a research area. Previous bibliometric studies have focused on a single specific innovation issue, such as innovation adoption (van Oorschot et al., 2018), open innovation (Randhawa et al., 2016), or disruptive innovation (Li et al., 2018). Others have relied on only one network approach (Lee and Sohn, 2016). To our knowledge, until now, no study has systematically investigated the whole body of literature on networks and innovation by using a state-of-the-art bibliometric analysis.

The goal of this article is to evaluate the current state of the research on networks and innovation. Our first group of research questions refers to the social organisation of the collective enterprise: What are the main disciplines and research areas focusing on networks and innovation? Which influential scholars, institutions, and countries contribute the most to advancing the area of networks and innovation? The second group of questions is related to the cognitive base and research fronts: Is the research production of networks and innovation based on a dominant school of thought or on different
coexisting research communities? Over time, how did the research area evolve? What are the current and emerging research patterns? In the current era when innovation is a major competitive factor for companies and at the top of many managers’ agendas, our study provides practitioners with a useful point of departure to identify the role of networks within innovation and the surrounding factors that connect networks and innovations.

We proceed in several stages. First, as a starting point to gather information, we define our conceptual space. Second, methods and data are outlined. Third, we show the characteristics of scientific production: the main disciplines working in the field, the field’s evolution over time, the contributing countries, the international collaborations, and the most cited and referenced publications. Fourth, through keyword co-occurrence, co-citation, bibliographic coupling analysis, and network analysis techniques, we identify and assess the different schools of thought and research communities. Finally, we outline the contributions and gaps in the area of study and identify avenues for future research.

2 The conceptual space on networks and innovation

Networks and innovation are considered a research area situated between overlapping multidisciplinary research fields. The term research field is frequently used to refer to broad enterprises in the organisation of knowledge production (Whitley, 1984). Research fields are usually cross-disciplinary endeavours in a preferential area of study, characterised by a shared knowledge base (a set of theories and common intellectual traditions) and an identifiable research community, often with common institutions such as journals and conferences. In contrast, a research area is a more specific set of interrelated problems of inquiry. They are formed by a complex network of researchers working on common topics, sharing a delimitation of aspects of the social reality, and using similar conceptual and methodological tools (Mulkay et al., 1975). In such a complex arena, a delimitation of the conceptual space is a necessary condition for guiding the bibliometric search strategy.

2.1 Network approaches

The concept of networks is broad, catch-all, polysemic and difficult to operationalise. Some scholars define a network practically as a set of actors and the relations among them (Wasserman and Faust, 1994). Others conceive of networks as an intermediate mode of organisation between hierarchies and markets (Powell, 1990; Thompson, 2003; Williamson, 1975), whereas a line of research emphasises the resources embedded in social relations (Adler and Kwon, 2002; Lin, 1999). Several approaches, rather than a single one, are employed to conceptualise and analyse networks. The three main approaches that transcend the network metaphor, and offer methodological ways to measure networks and the behaviours associated with them, are network analysis, social capital, and networking.

2.1.1 Network analysis

Network analysis is a theoretical and, above all, methodological approach to empirically examine relations among actors through the use of graph theory. Some of the advantages of network analysis are that it goes beyond the network concept and enables the
calculation of network properties, the identification of the specific positions of actors within networks, the identification of subgroups based on connections, and the analysis of network effects in a quantitative fashion (Borgatti et al., 2014). Consequently, network analysis has led to the growth of quantitative studies on the impacts of interactions, collaborations, and partnerships. Between 1990 and 2021, the amount of research using network analysis increased exponentially. A search of the scientific production of network analysis revealed that the number of articles per year increased from 120 in 1990 to 10,211 in 2021.1

Despite its popularity, network analysis has also attracted criticism. Network analysis has advanced more in terms of methodology than in terms of theory (Erikson, 2013). For example, algorithms have proliferated to detect communities and process large amounts of data without offering theoretical answers regarding the global operation of networks. On the other hand, some seminal works emphasised the structuralist perspective of network analysis (Wellman, 1988), whereas more recent manuscripts underscored agency over structure (Gulati and Srivastava, 2014). Finally, network analysis by itself is unable to explain any outcomes or causal conditions that are not associated with actors or ties, such as whether the cohesion of a network promotes a macro-level change. Networks alone do not explain causes or consequences. Therefore, it is necessary to incorporate other methods that shed light on the whole process, from the point when a network is formed until the results sought are obtained. Qualitative comparative analysis is one such method (Cárdenas, 2012).

2.1.2 Social capital

In parallel to the growth of network analysis, the concept of social capital emerged from a set of sociological theories that emphasised the benefits of social relations and the resources obtained through networks, such as trust, social support and cooperation (Bourdieu, 1986; Coleman, 1988; Putnam, 1995). While Bourdieu (1986) conceptualised social capital as an individual asset, Putnam (1995) suggested that social capital is a collective good. Social capital is not a single theory but rather an umbrella concept related to the effects of interactions. Unlike network analysis, social capital is more of a concept that tries to capture a set of explanatory mechanisms than a methodological tool. Although the concept of social capital is polysemic and multilevel, networks are present in all meanings of social capital. The concept of social capital highlights that networks and the resources accessed through networks have either positive or negative effects, which has motivated research on the consequences of trust, social support, cooperation, and organisational membership [see Son (2020) for an updated review]. Once again, networks are conceptualised as a structure that influences different sorts of behaviours.

One of the main concerns about social capital is the challenge of measuring the wide-ranging aspects included within the concept, such as networks, trust, sense of belonging, participation, social norms, social support, social cohesion, social inclusion, solidarity, and reciprocity. The lack of consensus on the measurements of social capital is also a reason for the popularity of this concept. Very often, social capital refers to any feature associated with collaboration, teamwork, organisational ties, trust, or collective action. Based on a search on Scopus, the number of articles on social capital grew from 198 in 2000 to 2,295 in 2021.2 The social capital approach has been extended to multiple disciplines to understand the effects on very different kinds of issues, such as happiness
(Leung et al., 2013), health (Kawachi et al., 2008), and, obviously, innovation (Dakhli and De Clercq, 2004).

2.1.3 Networking

Like social capital, networking is an umbrella concept used in very different forms. The main distinction between networking and other network approaches is the emphasis on action rather than structure. In the 1990s and 2000s, especially in the business sector, the use of the term networking was a trend that stressed information exchanges, informal meetings, and reciprocal commitments in managerial and organisational performance (Meier and O’Toole, 2003). Since then, networking has been applied to other areas, such as international cooperation, politics, and education. An analysis of the scientific production of networking indexed in Scopus shows that after 2010, networking became more prevalent in educational research than in management or business studies. The underlying reason could be the use of the term networking to refer to online social media activity. The digital revolution and the emergence of online channels of communication and information (Facebook, Twitter or WhatsApp) brought networking to the front line.

2.2 Innovation approaches

Although there are multiple definitions of the word innovation (Godin, 2017), the two most common can be labelled as the evolutionary view and the diffusionist view. They are used by sound research traditions and have prevailed over the years, in contrast to the less accepted definitions that are used by linear models and based only on some aspects of science and technology. The evolutionary view of innovation, also called the Schumpeterian view because of the intellectual influence of Joseph Schumpeter, is dominant in the field of innovation studies. The working definition of innovation is constructed around a set of key ideas: new combinations of existing knowledge, the distinction between invention and innovation, the classification of innovation into products, processes and organisations, and the associated distinction between incremental and radical impacts of the results of innovations (Borrás and Edquist, 2019). This approach is coherent with the core knowledge formed by evolutionary economics, the resource view of the firm, and innovation system frameworks, and it is consistent with both more advanced process models and interactive system models.

In contrast, the diffusionist view is based on a different conceptual elaboration. The working definition of innovation is grounded in adoption: innovation is an idea, practice, or object that is perceived as new and useful by an individual or other unit (Rogers, 1995). The nature attributed to innovation is more open to a range of phenomena behind technologies, material products, services, organisations, and commercialisation. That is why the cognitive lens of the diffusion perspective has led to wider areas of interest, methodological strategies, and research tools. In sum, different conceptualisations of innovation can lead to different areas of interest.
3 Methods and data

3.1 Data extraction and processing

This article analyses the scientific production of networks and innovation using bibliometric techniques. Scientific articles that were published in English and related to innovation and networks were selected from journals indexed in Scopus up to January 2022. We opted for Scopus because its coverage of social sciences and humanities is better than that of the Web of Sciences (Mongeon and Paul-Hus, 2016).

We used the conceptual space described above as a tool to direct our search. Regarding networks, the terms network analysis, social capital, and networking provide good coverage of the whole research field on networks. Regarding innovation, we used it as a single term. Over the years, the word innovation has proven to have some advantages as a social science concept compared to neologisms and other concepts taken from common sense language. It has proven useful for research because it is associated with the attributes of use or practicality, as opposed to discovery or invention (Godin, 2017). The term innovation represents a bridge between two classical domains of knowledge: the world of ideas and the practical world. Its combination with other related concepts, such as science and knowledge, would redirect the search to other research fields related to knowledge production and would not contribute to mapping the current state of research. Therefore, we did not add any variation or adjectives to the term innovation.

We searched all scientific publications that related to the innovation topic and the three terms related to network approaches: network analysis, social capital, and networking. The query was (TITLE-ABS-KEY (innovation)) AND (‘network analysis’ OR ‘social capital’ OR ‘networking’) AND (LIMIT-TO (SRCTYPE, ‘j’)) AND (LIMIT-TO (DOCTYPE, ‘ar’)). We selected only articles published in scientific journals and excluded reviews, proceedings papers, meeting abstracts and editorial materials. Complete information about each record, including the full list of references, was extracted from that citation index.

3.2 Analytical strategy

First, the following bibliometric descriptive statistics were analysed to describe the field: the time evolution of scientific production, the journals in which articles were published, the subject categories of journals, the countries of the institutions to which the authors were affiliated, the top contributing institutions, and the most cited articles in the field of networks and innovation. Second, several types of network analysis were performed.

a Co-authorship analysis: This technique depicts the co-author relationships between authors in the sample. The objective is to show the collaboration degree of these authors, detect research groups and schools, and determine the degree of international collaboration (Barabási et al., 2002).

b Keyword analysis: This procedure identifies the co-occurrence of the most important terms used by authors to describe the content of their work. This map allows the identification of the most relevant topics, their relationships in terms of meaning, and the detection of semantic clusters (Callon et al., 1983).
c Co-citation analysis: This technique is employed to uncover the seminal papers in a field of study and detect different fronts and perspectives. It is based on the co-occurrence of references in a bibliography (Small, 1973). This procedure is considered useful to explore the knowledge base of a given body of research.

d Bibliographic coupling analysis: In contrast to co-citation analysis, this technique analyses the co-occurrence of papers that cite similar works. This allows us to detect publications that address similar topics and to detect research lines within the field (Kessler, 1963). Although closely related to the procedure capturing the knowledge base, this other procedure captures the research fronts within a body of research.

Gephi 0.9.2 was used to perform the network analysis (examining co-authorship, keyword co-occurrence, co-citation, and bibliographic coupling) and plot the graphs. This software was used because its ability to visualise large networks is higher than other products. Modularity was used to identify highly dense communities (clusters of nodes) with few connections to other communities. The communities were identified by applying the Louvain method. In a comparative analysis of clustering techniques, the Louvain algorithm was found to be one of the best-performing methods (Lancichinetti and Fortunato, 2009).

4 Characteristics of the scientific production of networks and innovation

The first paper on networks and innovation was published in 1970 (Schaffer, 1970). Thereafter, 24,872 scientific articles were published in scientific journals until 2021. During this period, 258,276 articles on innovation and 167,429 articles on networks (including network analysis, social capital, or networking) were published in journals. Networks and innovation papers represent only 9.6% of all scientific production of innovation but 14.9% of all scientific production of networks. These preliminary data confirm that networks and innovation are an essential part of the literature on networks.

Scientific articles on innovation and networks are grouped into two main subjects: management of technology and innovation (18.1%) and business and international management (14.9%). However, these categories represent only 33% of publications, which confirms that this field of interest is spread throughout a wide range of research categories (economics, engineering, computer science, geography, and development, among others), showing a high degree of multi-disciplinarity. Although network approaches have important roots in sociological theories (Bourdieu, 1986; Coleman, 1988; Granovetter, 1985; White, 1981), only 2.3% (386 papers) of all research production of networks and innovation is published in sociology and political science journals. The scientific production of networks and innovation is concentrated mostly in management areas.

Figure 1 shows the evolution of the number of published papers according to the four main subject categories. The graph shows that around 2005, the number of articles about management and business increases faster than the number of articles about engineering and economics, which indicates that networks and innovation studies are gathered in the business field. This fact reflects the important paradigmatic shift in the interpretation of the main sources of competitive advantage for business corporations in the 1990s (Bolvijn and Kumpe, 1990). The interest in innovativeness replaced the interest in
efficiency, quality, and flexibility. Additionally, the popularity of networks in the 2000s and the search for ‘best practices’ to create, disseminate and implement innovation contributed to the emergence of the alliance between networks and innovation as an essential topic in the subject of management and business.

Figure 1  Evolution of the number of articles according to the four main research categories (see online version for colours)

The journals that published the most papers on networks and innovation are *Sustainability* (3.18%), *Technological Forecasting and Social Change* (1.99%) and *Research Policy* (1.39%). Table 1 contains a list of the ten journals that published the most of the articles. According to the Scimago Journal Rank (SJR), the venues with the highest impact are *Research Policy* (3.533) and *Technological Forecasting and Social Change* (2.336). It is interesting to note that the production is widely spread throughout different journals; the ten journals that published most of the articles account for just over 12% of the publications. In other fields of study, such as market innovation or knowledge management, the research production is more concentrated in a set of scientific journals (Gaviria-Marin et al., 2019; Sprong et al., 2021).

Overall, institutions across 138 countries, where 31,434 authors were affiliated, contributed to the field of networks and innovation. Table 2 presents the citation average and the number and proportion of authors and publications by country. The USA is the country accounting for the biggest amount of authors (16.5%) and publications (18.64%), followed by China, with 10.72% of the authors and 13.03% of the publications. Ranked third is the UK, with 12.02% of the publications. According to the citation average, the USA (37.19), China (34.31) and the UK (33.47) are the countries with the highest impact. The USA and the UK are the countries that contributed most to studies on networks and innovation until 2005 when the USA passed the UK. However, around 2010, China emerged to the top position, and in 2017, it reached the same number of publications as the USA.

A significant portion of the studies come from English-speaking countries, as is common in publications appearing in indexed journals. However, an important trend is the recent rise of China as a major contributor in this research area. Countries other than the major producers of scholarly research are also present in the sample. Authors from
Spain and Italy strongly contribute to the network and innovation literature, generating 7.26% and 6.58% of the publications, respectively. Spain and Italy are middle-sized research systems compared to systems in other countries, and they have the lowest patent activity of the countries that contributed the most to the area (see Table 2). Although the contributions of these countries may be related to specific characteristics of their research systems, these figures reflect the growing interest of catch-up countries in investigating the dynamics of the knowledge economy.

Table 1 The ten most frequent journals by the number of published articles

<table>
<thead>
<tr>
<th>Source title</th>
<th>Categories</th>
<th>Articles</th>
<th>% (N = 24,872)</th>
<th>SJR 2021</th>
<th>SJR 2021 quartil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>Geography, planning and development</td>
<td>792</td>
<td>3.18%</td>
<td>0.664</td>
<td>Q1</td>
</tr>
<tr>
<td>Technological Forecasting and Social Change</td>
<td>Business and international management</td>
<td>495</td>
<td>1.99%</td>
<td>2.336</td>
<td>Q1</td>
</tr>
<tr>
<td>Research Policy</td>
<td>Management of technology and innovation</td>
<td>346</td>
<td>1.39%</td>
<td>3.533</td>
<td>Q1</td>
</tr>
<tr>
<td>Journal of Business Research</td>
<td>Marketing</td>
<td>255</td>
<td>1.03%</td>
<td>2.316</td>
<td>Q1</td>
</tr>
<tr>
<td>Technovation</td>
<td>Management of technology and innovation</td>
<td>231</td>
<td>0.93%</td>
<td>2.069</td>
<td>Q1</td>
</tr>
<tr>
<td>European Planning Studies</td>
<td>Geography, planning and development</td>
<td>229</td>
<td>0.92%</td>
<td>1.241</td>
<td>Q1</td>
</tr>
<tr>
<td>Technology Analysis and Strategic Management</td>
<td>Strategy and management</td>
<td>209</td>
<td>0.84%</td>
<td>0.731</td>
<td>Q2</td>
</tr>
<tr>
<td>Journal of Cleaner Production</td>
<td>Environmental science</td>
<td>204</td>
<td>0.82%</td>
<td>1.921</td>
<td>Q1</td>
</tr>
<tr>
<td>International Journal of Innovation Management</td>
<td>Business and international management</td>
<td>199</td>
<td>0.80%</td>
<td>0.48</td>
<td>Q2</td>
</tr>
<tr>
<td>European Journal of Innovation Management</td>
<td>Management of technology and innovation</td>
<td>178</td>
<td>0.71%</td>
<td>1.023</td>
<td>Q1</td>
</tr>
</tbody>
</table>

Source: Own elaboration

To assess the international collaboration of countries, authors from the same country were aggregated into a single node. Figure 2 maps the international collaboration of countries. The link between two countries indicates that the authors affiliated with those countries have co-authored at least five papers. The size of nodes and labels indicates the average number of citations of a paper published with that country affiliation, and the colour denotes the region. The strongest collaborations are between the USA and China (254 collaborations, 4.1% of all collaborations), between the USA and the UK (195 collaborations, 3.2% of all collaborations), between the USA and Canada (154 collaborations, 2.5%), and between China and the UK (107 collaborations, 1.7%). China is connected in the network with several other European, North American and Asian countries, and its high production of networks and innovation is based on international collaborations. It is noteworthy that the countries with the highest impact (citation average) are also the ones with the biggest amount of international collaborations.
### Table 2  
The ten countries with the greatest numbers of authors, publications and average citations

<table>
<thead>
<tr>
<th>Country</th>
<th>Authors (N = 79,078)</th>
<th>Authors %</th>
<th>Publications (N = 24,872)</th>
<th>Publications %</th>
<th>Citation average</th>
<th>Ranking in patent activity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>13,069</td>
<td>16.53%</td>
<td>4,637</td>
<td>18.64%</td>
<td>37.19</td>
<td>1</td>
</tr>
<tr>
<td>China</td>
<td>8,474</td>
<td>10.72%</td>
<td>3,242</td>
<td>13.03%</td>
<td>34.31</td>
<td>2</td>
</tr>
<tr>
<td>UK</td>
<td>6,814</td>
<td>8.62%</td>
<td>2,990</td>
<td>12.02%</td>
<td>33.47</td>
<td>19</td>
</tr>
<tr>
<td>Spain</td>
<td>4,263</td>
<td>5.39%</td>
<td>1,806</td>
<td>7.26%</td>
<td>32.67</td>
<td>44</td>
</tr>
<tr>
<td>Italy</td>
<td>3,880</td>
<td>4.91%</td>
<td>1,637</td>
<td>6.58%</td>
<td>30.07</td>
<td>26</td>
</tr>
<tr>
<td>Germany</td>
<td>3,156</td>
<td>3.99%</td>
<td>1,421</td>
<td>5.71%</td>
<td>29.39</td>
<td>7</td>
</tr>
<tr>
<td>Australia</td>
<td>2,751</td>
<td>3.48%</td>
<td>1,188</td>
<td>4.78%</td>
<td>27.33</td>
<td>6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2,579</td>
<td>3.26%</td>
<td>1,117</td>
<td>4.49%</td>
<td>25.22</td>
<td>12</td>
</tr>
<tr>
<td>Canada</td>
<td>2,424</td>
<td>3.07%</td>
<td>989</td>
<td>3.98%</td>
<td>23.73</td>
<td>8</td>
</tr>
<tr>
<td>France</td>
<td>1,900</td>
<td>2.40%</td>
<td>888</td>
<td>3.57%</td>
<td>22.67</td>
<td>15</td>
</tr>
</tbody>
</table>

Notes: *patent activity: resident patent filing, total patent grants, patent in force, and growth in filings, per population; filings per GDP and total grant and filing growth as a share of world total (Bloomberg, 2019).

Source: Own elaboration

### Figure 2  
International collaboration (co-authorship) of countries (N = 44; arcs = 268) (see online version for colours)

Source: Own elaboration

Regarding the top contributing institutions (Table 3), European universities stand out. Of the 20 institutions with the highest number of publications, only one is from the USA and three are from China. Note that the universities that produce the most on networks and
innovation are not the top universities in the world ranking (Shanghai Ranking, 2022). Only three of the top 20 contributing institutions, Harvard University, the University of Cambridge and the University of Oxford, are from the top 20 universities in the world.

Table 3  Top 20 contributing institutions

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Number of publications</th>
<th>Academic ranking of world universities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsinghua University</td>
<td>China</td>
<td>169</td>
<td>26</td>
</tr>
<tr>
<td>Lappeenranta University of Technology</td>
<td>Finland</td>
<td>155</td>
<td>401–500</td>
</tr>
<tr>
<td>University of Wageningen</td>
<td>Netherlands</td>
<td>154</td>
<td>151–200</td>
</tr>
<tr>
<td>Chinese Academy of Sciences</td>
<td>China</td>
<td>148</td>
<td>---</td>
</tr>
<tr>
<td>University of Manchester</td>
<td>UK</td>
<td>146</td>
<td>38</td>
</tr>
<tr>
<td>University of Toronto</td>
<td>Canada</td>
<td>143</td>
<td>22</td>
</tr>
<tr>
<td>Lund University</td>
<td>Sweden</td>
<td>135</td>
<td>151–200</td>
</tr>
<tr>
<td>University of Cambridge</td>
<td>UK</td>
<td>134</td>
<td>4</td>
</tr>
<tr>
<td>Utrecht University</td>
<td>Netherlands</td>
<td>133</td>
<td>54</td>
</tr>
<tr>
<td>Universitat Politècnica de València</td>
<td>Spain</td>
<td>131</td>
<td>401–500</td>
</tr>
<tr>
<td>Erasmus Universiteit Rotterdam</td>
<td>Netherlands</td>
<td>128</td>
<td>87</td>
</tr>
<tr>
<td>University of Hong Kong</td>
<td>China</td>
<td>125</td>
<td>96</td>
</tr>
<tr>
<td>Harvard University</td>
<td>USA</td>
<td>122</td>
<td>1</td>
</tr>
<tr>
<td>Universidad Complutense de Madrid</td>
<td>Spain</td>
<td>121</td>
<td>201–300</td>
</tr>
<tr>
<td>University of Oxford</td>
<td>UK</td>
<td>117</td>
<td>7</td>
</tr>
<tr>
<td>Universitat de València</td>
<td>Spain</td>
<td>117</td>
<td>201–300</td>
</tr>
<tr>
<td>Cardiff University</td>
<td>UK</td>
<td>115</td>
<td>151–200</td>
</tr>
<tr>
<td>Politecnico di Milano</td>
<td>Italy</td>
<td>106</td>
<td>201–300</td>
</tr>
<tr>
<td>Georgia Institute of Technology</td>
<td>USA</td>
<td>101</td>
<td>151–200</td>
</tr>
<tr>
<td>University of Queensland</td>
<td>Australia</td>
<td>96</td>
<td>47</td>
</tr>
</tbody>
</table>

Source: Own elaboration

The analysis of the most cited and a referenced publications provides a descriptive picture of the characteristics of the research area. In particular, the most cited publications – the articles on networks and innovation with the highest number of citations – represent the most recent knowledge front. Meanwhile, the list of more frequent references – the papers and books referenced by the articles on networks and innovation – reflect the intellectual roots and knowledge base.4

Regarding the most cited publications, the work of Powell et al. (1996) on interorganisational collaboration is the article in the research area with the highest impact by far. Other influential publications cover a variety of topics, including weak ties and knowledge (Hansen, 1999), diffusion of innovation (Greenhalgh et al., 2004), intrafirm networks (Tsai and Ghoshal, 1998), structural holes and innovation (Ahuja, 2000), proximity and innovation (Boschma, 2005), intraorganisational networks and absorptive capacity (Tsai, 2001), knowledge and communities of firms (Brown and Duguid, 2001), assimilation of enterprise planning systems (Liang et al., 2007), and technology brokering (Hargadon and Sutton, 1997). The most cited publications were all issued in Q1 journals, and four of them were published in the journal Administrative Science Quarterly. Only one of the most influential papers is based on qualitative analysis.
Table 4
The most cited and referenced publications on networks and innovation

<table>
<thead>
<tr>
<th>Publication</th>
<th>Journal</th>
<th>Citations</th>
<th>Subject area</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powell et al. (1996)</td>
<td>ASQ</td>
<td>5,210</td>
<td>Sociology and political science</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Greenhalgh et al. (2004)</td>
<td>MQ</td>
<td>4,140</td>
<td>Sociology and political science</td>
<td>Theoretical review</td>
</tr>
<tr>
<td>Hansen (1999)</td>
<td>ASQ</td>
<td>3,746</td>
<td>Sociology and political science</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Tsai and Ghoshal (1998)</td>
<td>AMJ</td>
<td>3,692</td>
<td>Business and international management</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Boschma (2005)</td>
<td>RS</td>
<td>3,428</td>
<td>Social sciences (miscellaneous)</td>
<td>Theoretical review</td>
</tr>
<tr>
<td>Ahuja (2000)</td>
<td>ASQ</td>
<td>3,041</td>
<td>Sociology and political science</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Tsai (2001)</td>
<td>AMJ</td>
<td>2,690</td>
<td>Business and international management</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Liang et al. (2007)</td>
<td>MIS</td>
<td>2,374</td>
<td>Computer science applications</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Brown and Duguid (2001)</td>
<td>OS</td>
<td>2,108</td>
<td>Management and technology innovation</td>
<td>Theoretical review</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Publication</th>
<th>Journal</th>
<th>Citations</th>
<th>Subject area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohen and Levinthal (1990)</td>
<td>ASQ</td>
<td>2,584</td>
<td>Sociology and political science</td>
</tr>
<tr>
<td>Granovetter (1973)</td>
<td>AIS</td>
<td>1,503</td>
<td>Sociology and political science</td>
</tr>
<tr>
<td>Barney (1991)</td>
<td>JM</td>
<td>1,430</td>
<td>Business, management and accounting</td>
</tr>
<tr>
<td>Chesbrough (2003)</td>
<td>Book</td>
<td>1,291</td>
<td>Book</td>
</tr>
<tr>
<td>Fornell and Larcker (1981)</td>
<td>JMR</td>
<td>1,273</td>
<td>Business, management and accounting</td>
</tr>
<tr>
<td>Schumpeter (1934)</td>
<td>Book</td>
<td>1,254</td>
<td>Book</td>
</tr>
<tr>
<td>Teece et al. (1997)</td>
<td>SMJ</td>
<td>1,216</td>
<td>Business, management and accounting</td>
</tr>
<tr>
<td>March (1991)</td>
<td>OS</td>
<td>1,147</td>
<td>Business, management and accounting</td>
</tr>
</tbody>
</table>


Source: Own elaboration
<table>
<thead>
<tr>
<th>Publication</th>
<th>Journal</th>
<th>Citations</th>
<th>Subject area</th>
<th>Analysis</th>
<th>Publication</th>
<th>Journal</th>
<th>Citations</th>
<th>Subject area</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hargadon and Sutton (1997)</td>
<td>ASQ</td>
<td>1,741</td>
<td>Sociology and political science</td>
<td>Qualitative</td>
<td>Granovetter (1985)</td>
<td>JS</td>
<td>868</td>
<td>Sociology and political science</td>
<td></td>
</tr>
<tr>
<td>Barabási (2005)</td>
<td>Nat</td>
<td>1,629</td>
<td>Multidisciplinary</td>
<td>Quantitative</td>
<td>Powell et al. (1996)</td>
<td>ASQ</td>
<td>854</td>
<td>Sociology and political science</td>
<td></td>
</tr>
<tr>
<td>Morgan (1997)</td>
<td>RS</td>
<td>1,354</td>
<td>Social sciences (miscellaneous)</td>
<td>Theoretical review</td>
<td>Coleman (1988)</td>
<td>JS</td>
<td>830</td>
<td>Sociology and political science</td>
<td></td>
</tr>
</tbody>
</table>


Source: Own elaboration
Table 5  Communities and most representative keywords

<table>
<thead>
<tr>
<th>Size</th>
<th>Colour</th>
<th>Keywords</th>
<th>Freq.</th>
<th>Size</th>
<th>Colour</th>
<th>Keywords</th>
<th>Freq.</th>
<th>Size</th>
<th>Colour</th>
<th>Keywords</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Purple</td>
<td>Adoption</td>
<td>25</td>
<td>71</td>
<td>Yellow</td>
<td>Knowledge management</td>
<td>381</td>
<td>89</td>
<td>Purple</td>
<td>SMEs</td>
<td>3,661</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network</td>
<td>21</td>
<td></td>
<td></td>
<td>Networking</td>
<td>274</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Learning</td>
<td>221</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Green</td>
<td>Networking</td>
<td>25</td>
<td>65</td>
<td>Blue</td>
<td>Networks</td>
<td>349</td>
<td>85</td>
<td>Green</td>
<td>Social capital</td>
<td>3,527</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial districts</td>
<td>22</td>
<td></td>
<td></td>
<td>Social capital</td>
<td>321</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collective learning</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Blue</td>
<td>Internet</td>
<td>38</td>
<td>40</td>
<td>Purple</td>
<td>SMEs</td>
<td>264</td>
<td>49</td>
<td>Orange</td>
<td>Social network analysis</td>
<td>2,046</td>
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<tr>
<td></td>
<td></td>
<td>Survey</td>
<td>12</td>
<td></td>
<td></td>
<td>Entrepreneurship</td>
<td>239</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Brown</td>
<td>Diffusion of innovations</td>
<td>16</td>
<td>24</td>
<td>Brown</td>
<td>Technology</td>
<td>180</td>
<td>71</td>
<td>Blue</td>
<td>Open innovation</td>
<td>3,609</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Network</td>
<td>133</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Orange</td>
<td>Technology</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39</td>
<td>Dark blue</td>
<td>Entrepreneurship</td>
<td>3,039</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Information society</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: n: number of keywords, d: degree, a: arcs and freq.: frequency

Source: Own elaboration
To identify the intellectual roots of the field, we list the most referenced publications by the articles on networks and innovation (Table 4). Here, we find that most of the contributions are from sociology, issued in *The American Journal of Sociology* (Coleman, 1988; Granovetter, 1973, 1985). Granovetter is the only scholar with two contributions among the most referenced, thanks to his theories on weak ties and network embeddedness. Two theories on the innovation process are also among the most referenced: absorptive capacity (Cohen and Levinthal, 1990) and open innovation (Chesbrough, 2003). The authors working on networks and innovation predominantly cited publications external to the field. Only one of the most referenced publications, Powell et al. (1996), is from the area of networks and innovation.

In addition to identifying influential authors, this information reflects the evolution of the disciplinary composition of the research area. The intellectual tradition used to be concentrated mostly on sociology, evolutionary economics, and organisation science. In particular, the works of Cohen and Levinthal (1990) and Nelson and Winter (1977) are considered some of the bases of innovation studies in close connection to the emergence of the socioeconomic stream, inspired by the work of Schumpeter (also appearing as a major influence). The other major influence comes from sociology. Five of the 15 most cited references are from sociologists adopting structural approaches to networks and social capital, in addition to reference works in organisation science (March, 1991).

In contrast, the most recent evolution of the research area, as reflected in the list of most cited publications, appears much more concentrated on management and business, although social sciences oriented to specific problems (accounting, environmental science, computer science and the more general category social sciences) still have an important presence. The current research on networks and innovation appears to be a truly multidisciplinary field with multiple ramifications.

5 Bibliometric network analysis

5.1 Keyword co-occurrence analysis

We extracted 32,020 keywords from the downloaded articles. The connectedness of the terms was analysed through the co-occurrence of keywords in the papers. We analyse keyword co-occurrence networks over different periods of time to highlight the established and emerging research patterns. Figures 3, 4 and 5 show the network of terms that co-occur before 2000, 2001–2009, and 2010–2021, respectively. The sizes of the labels and nodes correspond to the frequency of the terms in the sample of articles. Colours represent the modularity of communities in which the term is structurally classified. The most frequent term, innovation, was removed because the centrality of that node distorted the graphical representation.

Before 2000, we observe a disconnected network (Figure 3). Within the largest component, we identified small communities that weakly connected to each other. Between 2001–2009, the keyword co-occurrence network becomes more connected and centralised around central topics such as knowledge management, social capital, and entrepreneurship (Figure 4). Finally, between 2010 and 2021, the most frequent keywords form a highly connected network (Figure 5). Despite the increasing number of articles, different network approaches selected, the variety of innovation views considered, and
the worldwide origin of papers, the keywords configure a single component in the last decade. And within this component, the communities are connected to each other.

**Figure 3**  Keyword co-occurrence network (before 2000) (see online version for colours)

*Source:* Own elaboration

The keyword analysis in the three periods shows the evolution of this research area. In the first period (before 2000), the most frequent keywords are internet, technology, networking and adoption, and the largest cluster of associated topics connects networking, industrial districts and collective learning. The articles published before 2000 mainly focus on the adoption and diffusion of innovations. Between 2001 and 2009, knowledge management and social capital emerge as dominant and central topics. Although the concept of knowledge management emerged in the 1960s, it is linked to the
success of organisations in the 2000s with the consequent proliferation of studies (Gaviria-Marin et al., 2019). In the last period (2010–2021), there is a great increase of keywords (twice as much as in previous periods), among which open innovation, SMEs (small and medium-sized enterprises), entrepreneurship, social media, knowledge management, social media, and social network analysis are the most frequent. Open innovation is commonly studied through the analysis of social media. The keyword SMEs is strongly connected to knowledge management. This association shows that knowledge management is frequently studied through samples of SMEs rather than large corporations. In sum, the keyword analysis over three different periods of time reveals more diversity and a stronger connectedness of topics.

Figure 4  Keyword co-occurrence network (2001–2009) (see online version for colours)

Source:  Own elaboration

5.2  Co-citation network

Co-citation analysis is a bibliometric technique for mapping referenced papers according to their joint citation frequency in a sample of publications. Co-citation analysis allows us
to detect which publications are the foundational references for the different research lines. From a sample of 0.716 million references, Figure 6 shows the co-citation network of the 217 most cited papers (<100 citations). Only ties with more than ten co-citations are plotted (arc = 5,789). The sizes of the nodes and labels represent the number of citations in the sample, and the colours of the nodes indicate the communities detected by the modularity.

**Figure 5** Keyword co-occurrence network (2010–2021) (see online version for colours)

![Keyword co-occurrence network](image)

*Source: Own elaboration*

Five large communities were detected by the Louvain algorithm (Q-modularity = 0.208). Table 6 displays the size of the communities and predominant subjects and keywords. The subjects of the papers were taken from the classification of their venues according to *All Science Journal Classification (ASJC)*, and the keywords were extracted from the titles of the papers. Communities represent consolidated schools of thought based on the fundamental characteristics of this area of research. Our interpretation of each community is based on evidence that is consistent with intellectual traditions. We describe the clusters focusing mostly on the associated research issues, levels of analysis, fundamental assumptions driving the links between networks and innovation, the conceptual variations related to networks, and the type of innovation.

**C1** The largest community, labelled *knowledge management of firms* (green in Figure 4), includes articles that focus mainly on the conditions and capacities of organisations, mostly firms, to innovate, as reflected in the keywords: innovation, firms, knowledge, and learning. The most cited publications are the well-known
works of Cohen and Levinthal (1990) about absorptive capacity and March (1991)
about organisational learning. The articles in this community have close connections
with works related to the resource-based theory of firms that focus specifically on
networks as resources. The main assumption driving these articles is that networks
provide access to new knowledge and learning. In particular, social integration,
knowledge infrastructure, and management support provided by networks are
considered to have a positive and significant impact on the link between absorptive
capacity and innovation. These articles typically use the evolutionary view of
innovation, with a focus on the generation of innovations consisting of a combination
of technology and organisational arrangements that improve the performance of
organisations.

Figure 6  Co-citation network (N = 217; arcs = 5,789) (see online version for colours)

Source:  Own elaboration

C2  The second largest community, labelled structural network approaches (orange),
comprises seminal papers on network approaches. The most representative words in
the titles are networking, social capital, and structural. The most influential
publications in this cluster, Nahapiet and Ghoshal (1998) and Coleman (1988), are
theoretical papers on social capital and the structural network conditions of human
capital. A prevailing perspective is that social capital stimulates knowledge exchange
and combination and aids in the creation of intellectual (or human) capital. Once
again, networks come first. Within this community, the highest proportion of
publications is issued in sociological journals. Regarding the impact on innovation,
although technological innovation is prevalent, publications cover a wide range, from the generation of several kinds of innovation (both technological and organisational) to processes of diffusion and assimilation.

<table>
<thead>
<tr>
<th>Community</th>
<th>Nodes</th>
<th>%</th>
<th>Subjects</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge management of firms</td>
<td>60</td>
<td>30%</td>
<td>Strategy and management (45%), management of technology and innovation (25%)</td>
<td>Innovation, firms, knowledge, learning</td>
</tr>
<tr>
<td>Structural network approaches</td>
<td>32</td>
<td>15%</td>
<td>Strategy and management (31%), public administration (25%), sociology and political science (22%)</td>
<td>Networking, social capital, structural</td>
</tr>
<tr>
<td>Open innovation</td>
<td>18</td>
<td>8%</td>
<td>Business, management and accounting (33%), management of technology and innovation (28%)</td>
<td>Open innovation, sources</td>
</tr>
<tr>
<td>Structural modelling</td>
<td>11</td>
<td>5%</td>
<td>Marketing (36%)</td>
<td>Structural equations</td>
</tr>
<tr>
<td>Clustering and proximity</td>
<td>5</td>
<td>2%</td>
<td>---</td>
<td>Clustering, proximity</td>
</tr>
<tr>
<td>Total</td>
<td>217</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own elaboration

C3 The third community is focused completely on open innovation (blue). The most representative publication in this cluster is the seminal book on open innovation by Chesbrough (2003). The topic of open innovation, also highlighted in the keyword network, stands out in the research area of networks and innovation. Open innovation refers to the use of internal and external sources of ideas to accelerate innovation and expand the market. Here, network approaches become necessary to analyse the complex set of actors and relationships involved in the process of innovation. With regard to settings, the research is concentrated on firms (although other organisations are present). Open innovation was a model originally employed to understand how firms advance their technology, but more recently, it has focused on innovation as the conversion of ideas into value for organisations.

C4 The fourth community (purple), labelled structural modelling, comprises methodologically oriented manuscripts. The most representative keyword is structural equations, and papers are published mostly in marketing journals. The most cited publications in this cluster are Fornell and Larcker (1981) and Podsakoff et al. (2003), two papers assessing explanatory models. Because research on networks and innovation has emphasised networks as an explanatory variable and innovation as an outcome, explanatory statistical techniques have gained relevance within the area for testing these models.

C5 The fifth and smallest community (brown) is labelled clustering and proximity. The most cited paper is Boschma (2005), which showed that geographical proximity facilitates interactive learning and that proximity might also have negative consequences for innovation due to the problem of lock-in. This community of manuscripts related to clustering is strongly linked to the structural network
approaches community. They share their intellectual roots in the research field of innovation, although one of the major differences is the level of analysis. In relation to clustering and proximity, manuscripts focus mostly on innovation systems of a territorial or a sectorial nature. In such systems, networks form the structure of relationships between actors that facilitates knowledge exchange. In this community, an interactive view of innovation systems prevails, focusing mostly on the interface between technological and economic innovation.

5.3 Bibliographic coupling analysis

Bibliographic coupling allows the grouping of papers according to their citation pattern. In graphical terms, it shows the distances between papers according to their similarities in citing other publications. This analysis permits us to observe groups of publications related to specific lines of research within a discipline. Different from co-citation analysis, bibliographic coupling paints the most recent picture of a discipline. This technique can be considered the inverse of co-citation analysis because while co-citation shows referenced publications, bibliographic coupling depicts citing articles. Articles on networks and innovation are connected if they have common references; the more connected they are, the more similar their knowledge base is.

Figure 7 Bibliographic coupling network (N = 2,053; arcs = 35,131) (see online version for colours)

Source: Own elaboration
Figure 7 graphs the bibliographic coupling of 2,053 out of the 16,974 articles, representing 12% of the publications on network and innovation. It considers only ties between publications that co-occur more than ten times. The sizes of the nodes and labels correspond to the number of citations in Scopus, and a modularity algorithm was used to colour the nodes. The fact that bibliographic coupling can be considered the inverse of co-citation allows us to contrast the two types of analyses and to link the relationships between the groups of each model.

Table 7 shows three communities detected with the modularity algorithm. In contrast to Table 6, subjects in Table 7 are determined based on the journal classification, while keywords are extracted from the author keywords of each article. It is common to find substantial similarities between clusters resulting from co-citation analysis and bibliographic coupling, especially in the social sciences, where the pace of knowledge production is lower and paradigms coexist in longer time frames than in other knowledge domains. However, in specific areas, such as networks and innovation, subtle differences in the clusters can be used to trace the evolution of a problem area. When interpreting this set of clusters, we focused on the characteristics that distinguish the communities. Each community represents a cluster of articles on networks and innovation with shared backgrounds and sources:

C1 In the first community, network embeddedness of innovation (purple), the most frequent keywords are social capital, social networks, and absorptive capacity. The most cited papers in this cluster are Tsai and Ghoshal (1998), which tested the role played by the dimensions of social capital in product innovation, and Ahuja (2000), which analyses firms’ ego networks and their subsequent innovation output. The most cited articles are all issued in the late 1990 and early 2000. The most central articles, those with the highest degree centrality, in this set are all about the impact of interfirm or intrafirm networks on innovation (Abdirahman et al., 2014; Casanueva Rocha et al., 2010; Chiu and Lee, 2012; Liu et al., 2011; Shan et al., 2018). The most cited and most central papers underscore the multilevel network embeddedness of innovation. The USA and China are the countries that contribute most in this community.

C2 The second community, labelled knowledge management (orange in Figure 7), includes publications characterised by the terms absorptive capacity, knowledge management, and product innovation. The most cited papers in this cluster were published in the 2000s and focus on organisational processes and routines: centralisation and formalisation (Jansen et al., 2006), entrepreneurial orientation (Lee et al., 2001), exploration and exploitative learning (Raisch et al., 2009), and knowledge creation (Nonaka and von Krogh, 2009). The most central articles analyse external and internal sources of knowledge and highlight the role of networks in the knowledge creation process. Whereas the first cluster focuses mostly on showing how network embeddedness influence innovation, this second cluster represents a step beyond because papers investigate the specific mechanisms or organisational processes of knowledge acquisition that connect networks and innovation. Most of these papers come from institutions in the USA, Spain and China.

C3 Finally, the third community, open innovation, is characterised by open innovation, SME issues, and collaboration. The origins of this set of papers are mostly from
Europe, including Italy, Spain and the UK. The most central publications in this cluster are all applications of open innovation. The most cited papers are the introduction of a special issue about open innovation co-authored by Chesbrough (Enkel et al., 2009) and a state-of-the-art on open innovation (Huizingh, 2011). The top 5 most cited publications in this set were published in the late 2000s and early 2010.

Therefore, the three clusters represent an evolution of the research area: network embeddedness (which used sources published in the late 1990s and early 2000s), knowledge management (which cited papers issued in the 2000s), and open innovation (which cited papers from the late 2000s and early 2010). Although all of these communities can be considered distinctive clusters, they are all connected; there are no isolated large clusters or schools of thought (intellectual traditions).

Table 7  Communities detected by the modularity algorithm and subjects, keywords and countries associated with each community cluster

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Nodes</th>
<th>%</th>
<th>Subjects</th>
<th>Keywords</th>
<th>Countries and (frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network embeddedness (purple)</td>
<td>805</td>
<td>39.2%</td>
<td>Management of technology and innovation (17.9%); strategy and management (16.7%)</td>
<td>Social capital, social networks, absorptive capacity</td>
<td>USA (476), China (246), Spain (207)</td>
</tr>
<tr>
<td>Knowledge management (orange)</td>
<td>853</td>
<td>41.5%</td>
<td>Management of technology and innovation (19.8%); strategy and management (15.8%)</td>
<td>Absorptive capacity, knowledge management, product innovation</td>
<td>USA (451), Spain (332), China (273)</td>
</tr>
<tr>
<td>Open innovation (green)</td>
<td>395</td>
<td>19.2%</td>
<td>Management of technology and innovation (21%); strategy and management (15.2%)</td>
<td>Open innovation, SMEs, collaboration</td>
<td>Italy (208), Spain (110), UK (96)</td>
</tr>
<tr>
<td></td>
<td>2,053</td>
<td>100.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own elaboration

6 Discussion and conclusions

This article has provided a detailed overview of academic research on networks and innovation. The main distinctive feature of the study is the coverage of all articles published in journals listed in Scopus. This approach prevents biased selection by researchers when exploring a complex research area and provides a comprehensive exploration of the existing literature. Our bibliometric analysis has facilitated the identification of the underlying structure, theoretical foundations, key themes, influential scholars, major collaborations, and research gaps in this research area. Our main contribution is that we empirically detect the main trends in the intellectual structure of the research area. We find that the research on networks and the research on innovation have some common intellectual roots, but at the same time, they have evolved as
organised in a set of research communities. The findings reflect some of the main issues for current discussions and avenues for further research.

Research on networks and innovation is dispersed; it is not concentrated in a few journals or in a few countries or published by a few authors. Its contents, however, are similar, focused mainly on organisations and managerial issues. Although networks and innovation are ubiquitous and dozens of diverse disciplines have focused on them, scientific production has mostly concentrated on management and business subjects. However, while management studies keep this field alive, its intellectual roots are in sociology (Burt, 1992; Coleman, 1988; Granovetter, 1973, 1985). The top cited scholars on innovation in management studies, such as Calantone et al. (2002), Christensen et al. (2004) and Cooper (1999), are not among the most referenced sources in the research area of networks and innovation. Therefore, network approaches seem to prevail over innovation frameworks in the analysis of networks and innovation, which can explain the prevailing perception that innovation is almost always an outcome of network structures.

The identification of clusters shows at least three large, distinguished research communities: those that focus on firm collaboration networks, knowledge management and absorptive capacity, and open innovation. The several network analyses performed (keyword co-occurrence, co-citation, and bibliometric coupling) also demonstrate the connectedness of the different research communities. The cross-cutting topics that link the field are knowledge in its varieties (knowledge management, knowledge sharing, and knowledge exchange) and the structuralist view of networks and innovation (studies place networks as an independent variable and innovation as a dependent variable). Therefore, the existence of different network approaches – network analysis, social capital, and networking – generates cohesion rather than division across the research area.

The bibliometric results reveal research gaps and suggest avenues for further inquiry. First, the findings show that a large part of the hypotheses on networks and innovation have been tested at the firm level and not in other units of analysis, such as countries or cities. A research cluster focused on country-level studies is lacking. Given the substantial concern over the politics of innovation (Taylor, 2016), future lines of research should further explore the role of ‘societal’ social capital – social trust and membership in organisations – in different aspects of innovation. Second, in the analysis conducted, we did not find keywords associated with institutions or culture. This absence shows that networks are not usually analysed together with realities of symbolic nature, such as values, cognitive scripts, norms and institutions. Future research should confront this puzzle of conditioning factors in order to serve policymakers and other practitioners. Third, social innovation should be incorporated into the agenda to move network and innovation studies away from overdependence on business organisations and toward other informal social settings, such as online communities or neighbourhoods. Finally, we found a research gap concerning the impact of innovation on networks. This is where the networking approach can contribute to advancing the field since networking characterises interactions as a dynamic agent-based action rather than a relational structure.

The present study can help scholars who are approaching this topic and aiming for a comprehensive overview of the scientific literature produced thus far. Scholars can leverage the results of this study to inform future studies considering the proposed avenues for future research. However, this study is not free of limitations. First, this bibliometric analysis was performed based on information extracted from journals published in English, where the findings are biased toward Western views. Since China has become a dominant player in this research area, the analysis of publications indexed
in China National Knowledge Infrastructure (CNKI) could reveal other insights. Second, reviews conducted through bibliometric analysis make it difficult to capture more precise findings, such as the mechanisms between networks and innovation. A deeper content analysis of the top-cited and top-referenced publications is recommended for further research.

Finally, we conclude with a point of concern regarding the geographical inequality in the scientific production of networks and innovation. Although the most active institutions in this area are not the top universities in the world, which suggests widespread interest in networks and innovation, the share of publications from Latin America, Eastern Europe, and Africa is very limited. This fact suggests that the knowledge transfer about networks and innovation to practitioners in developing economies continues to be based on datasets and insights from advanced economies. Notably, China has emerged as a top contributing country in this research area, especially due to its international collaborations. The Chinese Government assumed that the country’s fast and sustainable economic development could not be achieved without making huge investments in universities and encouraging academic partnerships and scientific networks (Bratianu, 2020).

Acknowledgements

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References


Notes
1 Data were based on a search of the term ‘network analysis’ on Scopus database and were limited to articles published in scientific journals (‘j’). The query was (‘network analysis’) AND (LIMIT-TO (SRCTYPE, ‘j’)) AND (LIMIT-TO (DOCTYPE, ‘ar’)).
2 Data were based on a search of the term ‘social capital’ on Scopus database and were limited to articles published in scientific journals (‘j’). The query was (‘social capital’) AND (LIMIT-TO (SRCTYPE, ‘j’)) AND (LIMIT-TO (DOCTYPE, ‘ar’)).
3 Since 2000, research communities in some social science disciplines in Spain and Italy have grown steadily with an international orientation, especially in business, management, and related social sciences. Publications in international journals have been propelled by the evaluation systems (Fernández-Esquinas, 2020).
4 In the list of the most referenced manuscripts, articles and books are included.
5 A component is a part of the network where all nodes are connected directly or indirectly by some path.