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Article

Worldwide Research on Open Innovation in SMEs

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Abstract: Research on open innovation (OI) has increased in recent years, showing its potential in various areas of knowledge. Its relation to small and medium-sized enterprises has attracted the attention of academics. This article aims to evaluate the intellectual structure of the scientific study of OI, and its close relationship with various scientific fields, through a bibliometric analysis of this academic field using the Scopus database and the application of the VOSviewer software. The methodology comprises a rigorous systematic and transparent process divided into four phases: (i) the establishment of search criteria for the research field, through a literature review for its selection; (ii) the selection of the database, the establishment of the search equation and extraction of information; (iii) the application of inclusion and exclusion criteria for the selected documents and an explanation of the usefulness of the software; and (iv) the analysis of the results through the approaches of scientific output performance and bibliometric mapping. The results show an increasing trend of IO publications in SMEs, consolidated in 396 articles with contributions from 65 countries and 947 authors. The intellectual structure shows seven themes related to firm performance, R&D networks, business management, business models, capabilities and knowledge transfer. This study contributes to the field by providing an overview of IO in SME contexts. It also provides insightful information to policymakers for developing policies for firm economic growth.

Keywords: bibliometric analysis; co-citation analysis; open innovation; small and medium enterprise; SMEs

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1. Introduction

Open innovation (OI) has become a topic that has aroused interest in business and academia in various disciplines, such as management, economics and social science [1–3]. Henry Chesbrough expounded this theory in 2003 when he developed a conceptual framework to describe the transformation that some companies were undergoing in the way that they were managing innovation; that is, the transition from, what he called, a closed to an open approach [4–6]. This type of innovation is viewed as a paradigm shift, as organizations can obtain inflows and outflows of knowledge to enhance their innovation efforts [7,8]. Some researchers have refined this idea, considering that this information and knowledge exchange flows through three modes: (i) inbound (outside-in), related to the acquisition of external knowledge to create internal innovations; (ii) coupled, linked to co-creation; and (iii) outbound (inside-out), characterized by knowledge transfer [9–11].

OI is driving companies to reinvent themselves and participate in this innovation process [12,13]. This business model allows firms to be more effective at creating and capturing

value, obtaining collective intelligence and saving costs, time and new revenue opportunities [14–16]. The study of this type of innovation has various approaches, such as the triple helix model of university–industry–government collaborative relationships [17–19], governance theories [20,21] and absorptive capacity [22–24]. In addition, other authors have inquired about its effects on requirements and strategies [16,25,26], levels of engagement [27,28], practices and routines for managing open innovation [29–31] and risks and barriers [16,32,33].

Consequently, open innovation research occurs in various economic activities, such as manufacturing and high-tech industry [34,35] and SMEs and large enterprises [29,31,36]. In this context, SMEs have received increasing interest from the academic world in recent years, demonstrating improvements in their innovation capacity, their adaptation to open innovation practices and their benefits for the economy [29,36–38].

SMEs play a crucial role in the global economic context by representing approximately 90% of businesses and 40% of GDP in developing economies, and generating two thirds of the world's jobs [39–41]. Despite this importance, these types of companies face limitations compared to large firms, such as scarcity of monetary funds [29,42,43], difficulty in hiring specialized workers [44–46], leadership deficiencies [47], lower absorptive capacity [48] and deficiencies in value capture [49,50]. However, their size can offer some advantages, such as focusing on a niche market to increase their expertise, flexibility and speed in implementation and decision making [16,38,51].

Open innovation applied in SMEs is attractive because it allows them to generate alliances with large companies due to their high profitability and high specialisation capacity; this collaboration in the creation process allows them to have some intellectual protection [15,31]. Additionally, these types of companies can achieve improvements in innovation quality, performance and access to low-cost resources through the implementation of OI practices, such as networking, joint development, external sourcing and commercialisation, among others [52–55]. Furthermore, this has made it possible to establish business models [26], innovation systems [56] and knowledge management practices [57,58]. Taken together, the activities mentioned above have been fundamental pillars of the effects of applying OI to firms [59,60].

Some authors have considered studying open innovation in SMEs globally through literature reviews [36,61–63] and empirical studies at the national level on its applications [29,43,64]. Other researchers considered studying its scientific structure using the Web of Science database between 2007 and 2017 [65]. Despite these scientific contributions, knowledge on the composition and evolution of open innovation in SMEs is scarce. Therefore, performing a bibliometric analysis would allow the global review of the publications that make up its structure and complement the preceding studies.

The bibliometric analysis allows an exploration of the intellectual structure of a field of study, determining its characteristics and areas of research through the quantitative evaluation of the existing academic literature [66,67]. In addition, it allows the identification of emerging research areas and collaboration between institutions and researchers [68]. Finally, these analyses make it possible to evaluate the performance of scientific publications and map their structure through a visualization of the field of study by employing a bidimensional network [69,70].

The present study aims to evaluate the intellectual structure of OI in SMEs through a bibliometric analysis using the Scopus database to determine its performance, evolution and patterns. This research has two approaches: (i) performance analysis, which involves knowing authors, countries, journals and outstanding publications and (ii) science mapping, which involves the visualisation of the cognitive structure of this field of study through co-occurrence and co-citation analyses. Based on the above discussion, we address the following five research questions:

RQ1: What is the publication trend concerning open innovation in SMEs?
RQ2: Who are the most productive and influential contributors (authors, countries, and journals) to this topic?
RQ3: What are the most influential publications concerning OI in SMEs?

RQ4: What are the themes and topics associated with this intellectual structure?
RQ5: Which authors and journals constitute the intellectual structure in this area?

This research is structured in five sections: first, the introduction, which includes a brief bibliographical review of this field of study and the objective of the study; second, materials and methods, which details the database used and the systematic process of data collection and data cleaning, as well as the software used; third, the results related to the intellectual structure in terms of its performance, topics and the lines of research that comprise it; fourth, the discussion of the central relationships of the results obtained; finally, we include the conclusions and limitations of this study.

2. Materials and Methods

Analytical review schemes are necessary to evaluate the scientific literature [71]. Systematic reviews play a fundamental role in building knowledge and future lines of research [72]. These reviews involve a rigorous and transparent process that allows their reproduction and that minimizes errors through a comprehensive literature review [73]. Bibliometric studies present a formal and rigorous process similar to systematic literature reviews [68,74].

2.1. Research Approach: Bibliometric Analysis

This study adopts a bibliometric analysis approach. Bibliometrics is a scientific field that quantitatively studies the scientific production of an academic discipline or research topic through mathematical and statistical methods [75,76]. These studies facilitate understanding the cognitive structure by analysing its performance (authors, countries, institutions) and visualization through bibliometric mapping [70,77]. Therefore, they exhibit relevant information that complements literature reviews [78,79]. This approach belongs to the three most important literature review methods: systematic literature review, meta-analysis and bibliometric analysis [66]. These bibliometric studies have made contributions in various fields of knowledge, such as management [80–82], economics [83,84] and education [85,86]. Furthermore, bibliometrics has captured the attention of scholars in recent years due to its usefulness for a broad understanding of research fields [66].

2.2. Bibliometric Research Methodology

This work follows a methodological process consisting of four phases (see Figure 1): (i) search criteria for the research field, (ii) database search and extraction of documents, (iii) inclusion and exclusion criteria for documents and software used and (iv) results and analysis.

2.2.1. Phase I: Search Criteria for the Research Field

This study aims to analyse the structure of the academic field of open innovation as an essential factor in small and medium-sized enterprises. The terms selected as search criteria were "Open Innovation" and "Small and medium-sized enterprises" (including "SMEs" and other related expressions). This selection made it possible to construct the database.

2.2.2. Phase II: Database Search and Extraction of Documents

Bibliometric studies require information from a reliable, high-quality and wide coverage database. Thus, Web of Science (WoS) and Scopus databases are widely used, e.g., [68,87,88]. However, in the present study, Scopus is selected for the following reasons: (i) it presents a wide coverage of scientific output in the various areas of knowledge by indexing 66% more journals than WoS [89]; (ii) it has better coverage (in terms of time) compared to other databases [90]; (iii) it has indicators of the quality of scientific outputs, such as Citescore or Scimago Journal Rank (SJR) [89]; (iv) ease of access to bibliographic sources [91]; and (v) institutional access availability.

The data were extracted from the Scopus database in October 2021, using advanced search parameters and Boolean operators, which allowed the following search equation (Topic search): TS = (TITLE-ABS-KEY ("open innovation")) AND ((TITLE-ABS-KEY

("small business") OR TITLE-ABS-KEY ("medium business") OR TITLE-ABS-KEY ("small-sized firm") OR TITLE-ABS-KEY ("medium-sized firm") OR TITLE-ABS-KEY ("small and medium-sized business") OR TITLE-ABS-KEY ("SME*") OR TITLE-ABS-KEY ("small firm*") OR TITLE-ABS-KEY ("medium firm*") OR TITLE-ABS-KEY ("small enterprise*") OR TITLE-ABS-KEY ("medium enterprise*") OR TITLE-ABS-KEY ("small and medium enterprise*") OR TITLE-ABS-KEY ("small and medium-sized enterprise*"))). The total number of documents obtained was 683.

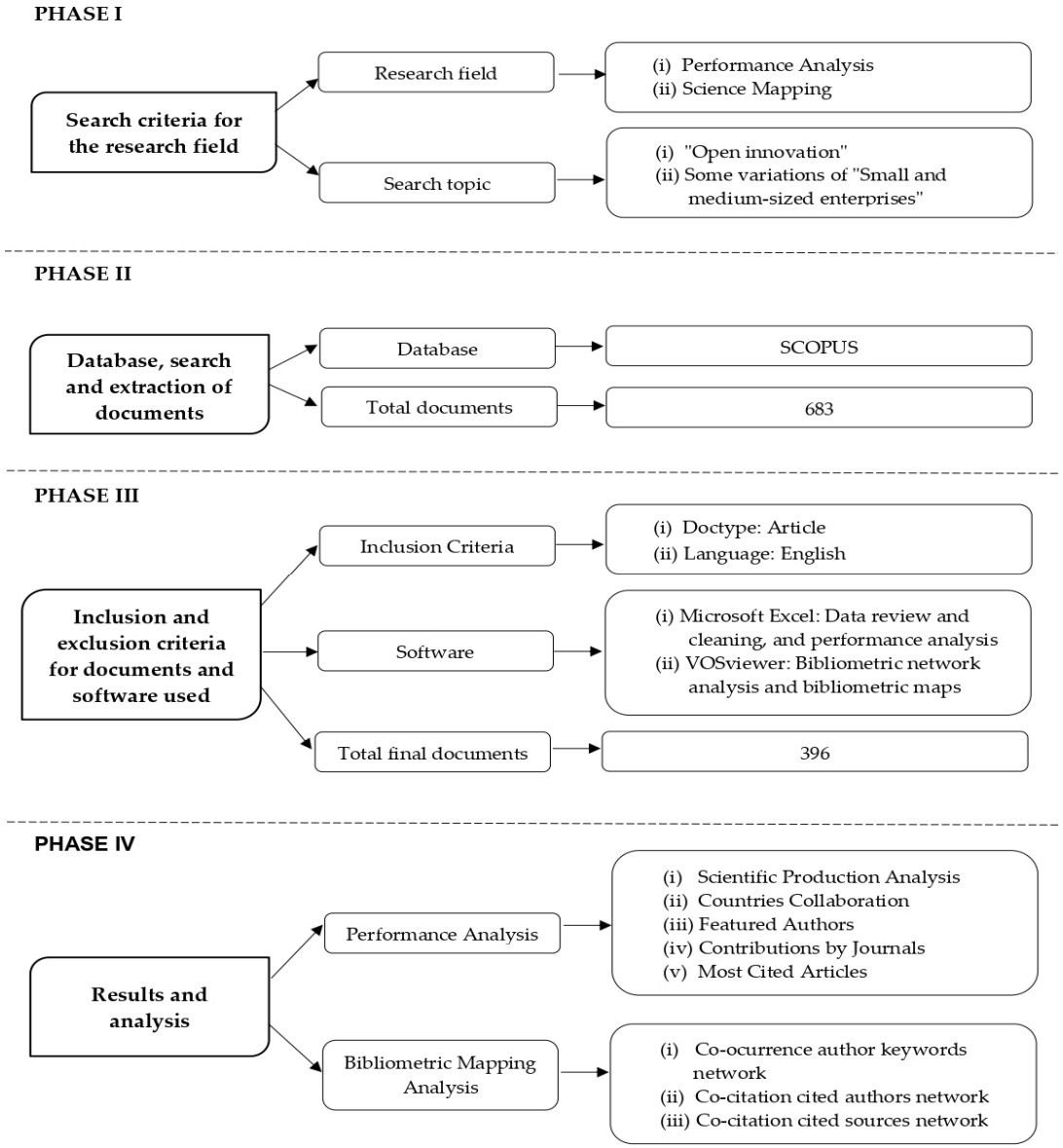

Figure 1. Bibliometric research methodology.

2.2.3. Phase III: Inclusion and Exclusion Criteria for Documents and Software Used

In this phase, we established the criteria by which to process and refine the information. We selected only articles (excluding other types) because they are the most representative of the scientific outputs and are catalogued as high quality due to their peer review [92]. Additionally, we included articles in English, as it is the principal language of scientific dissemination [93,94]. The total number of documents obtained was 397.

The extracted data is in CSV format (comma-separated values), which includes variables related to citation information (authors, document titles and year of publication,

sources and citations, among others), bibliographic information (affiliations, languages), abstract, keywords and references. The two software used for the analysis are:

(i) Microsoft Excel: It allowed the review of outliers in the data, which ensures the quality of the information for the study [77,95]. Likewise, we cleaned the errors and duplicates from the data extraction using variables, such as author, language, type of document and missing data [88,96]. After we corrected these errors, 396 documents remained. In addition, the software allows analysing the performance of scientific outputs according to various units of analysis, such as documents, authors, countries and journals [70,97].

(ii) VOSviewer: It is an open-access software developed by The Centre for Science and Technology Studies of Leiden University (Netherlands). This software allows the construction of two-dimensional bibliometric networks. This network shows the cognitive structure of the field of study, called bibliometric maps or science maps [98]. These maps allow a close analysis of the structure from its nuclear (co-occurrence of keywords), meso (co-citation of cited authors) and peripheral (co-citation of cited journals) parts [91,99]. Various academic disciplines implement this software to analyse cognitive structures [100–105].

2.2.4. Phase IV: Results and Analysis

The bibliometric analysis comprises two approaches: (a) the analysis of the performance of the scientific structure through publications, year of publication, the number of papers produced, countries, authors and affiliations; (b) bibliometric mapping, which allows the representation of the relationships between fields and subfields of knowledge [106,107].

3. Results

3.1. Performance Analysis

3.1.1. Scientific Production (RQ1)

A total amount of 396 scientific articles have been considered from the academic community that studies OI in SMEs. Figure 2 shows the publications from the last 15 years of research (2007–2021) which have received 9766 citations. Initially, studies on this topic were scarce, although there is a growing interest from the academic community, where 52% of published scientific production occurred in the last four years (2018–2021).

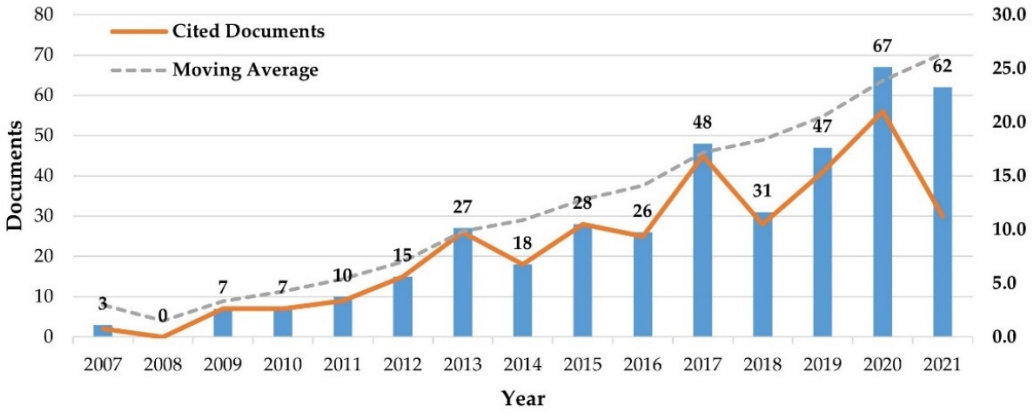

Figure 2. Evolution of scientific production.

The first studies in this field address regional open innovation systems [108], innovation policies in the European Union [109] and external knowledge management for new products [110]. During this period (2007–2010), publications related to the management of open innovation activities [29,111], networks and cooperation agreements [43,112–114] and public policies for the promotion of SMEs [46,115]. Other studies focused on the

absorptive capacity of SMEs [23], firms' dependence on external sources of knowledge and their positive effects on production [116], as well as the use of Web 2.0 [117].

In 2011–2020, we observed the higher development of this field of study, with scientific output increasing by 317 papers (80% of the total). In this decade, the research focused on the commitment of SMEs to assuming open innovation in their processes [3,27,118,119], the establishment and use of business models [120–123], business practices [31,124–126] and the development of OI through local and global networks [127–130]. OI has been studied from the perspectives of absorptive capacity [23,35,131–133], technological capabilities [134–136], dynamic capabilities [137,138], sustainability [139,140] and stakeholder theory [141–144]. Other scholars considered their benefits, examining firm performance [145–149], innovation performance [150–153] and customer performance [133].

In 2021, studies considered open innovation as a driver of organizational performance [154], innovation strategies [155–157] and the adoption of eco-innovation [158–160]. It is important to note that 2017 presented the highest growth rate, reporting an 84% increase, followed by 2013 with 80%. In addition, the moving average analysis revealed an increasing trend in scientific output (see Figure 2).

3.1.2. Collaboration between Countries (RQ2)

This type of analysis is performed according to the author's affiliation in this field of study, allowing us to know the various existing relationships between countries for the generation of knowledge [69]. For example, Figure 3 shows the collaboration of 65 countries, most of them being developed countries because OI is more often practised in these scenarios [161].

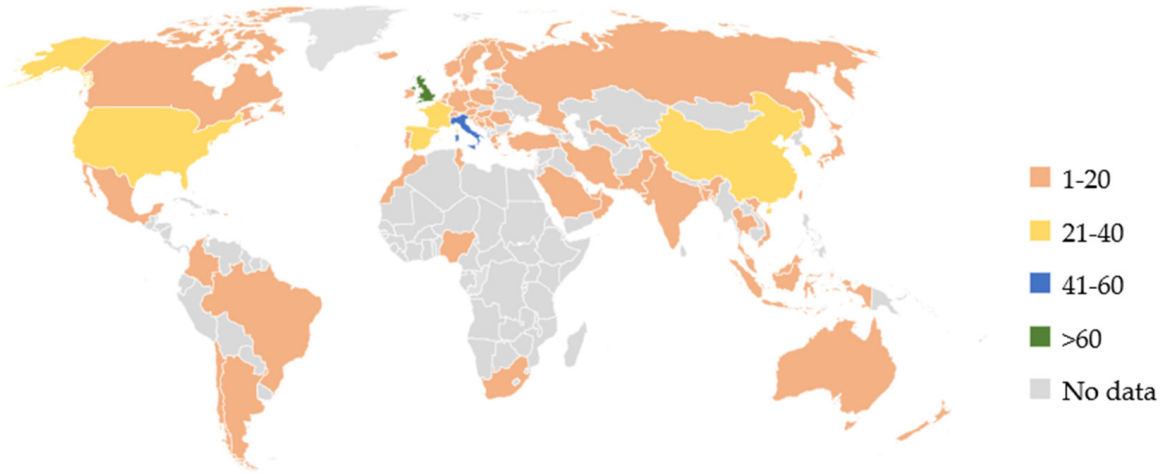

Figure 3. Contribution by country.

The United Kingdom has the most publications (63) and the highest number of citations (2195). Moreover, its research has involved the participation of 29 countries, especially France and Italy (seven and six papers, respectively). The first relationship with France involved the study of entrepreneurship as a function of OI [162–164] and proposals to implement and strengthen this type of innovation [108,144]. In the second relation to Italy, researchers address the various determinants for enterprises in terms of their preference for a specific mode of incoming open innovation, whether informal or formal [165], the role of information and communication technologies (ICTs) and big data in firms' innovation performance [166] and the various forms of governance in University–Industry interactions [167].

Italy is the country with the second most contributions in this field of study (57) and with the collaboration of researchers Alberto Di Minin (Sant'Anna Scuola Universitaria Superiore Pisa), Gabriele Santoro (Università degli Studi di Torino) and Manlio Del Giudice (Sapienza Università di Roma), who present studies focused on the innovation of digital technologies [166,168–170] and open innovation practices of SMEs [3,171]. Spain is the

country with the third most contributions (31). The participation of Jose Luis Hervas-Oliver (Universitat Politècnica de València), Sabine Brunswicker (Research Center for Open Digital Innovation and affiliated to ESADE in 2015), and Wim Vanhaverbeke (Universiteit Antwerpen and affiliated to ESADE in the period from 2010–2020) has helped the dissemination of scientific literature on open innovation with a focus on SMEs [55,111].

In the top 10 countries, there are seven European countries (the United Kingdom, Italy, Spain, France, Germany, Belgium and Sweden), two Asian countries (China and South Korea) and one from the American continent (the United States). It is worth mentioning that the United Kingdom, Italy and Spain have published two papers in the context of entrepreneurship theory [162,164], whilst China and the United Kingdom have studied firms' absorptive capacity [172,173].

Figure 3 shows the detailed contributions by country, where 52 countries show a low contribution in this field of study. Eleven of them have only one paper, with Switzerland standing out, whose only publication is among the most cited with 1180 citations [29]. Europe has the most significant number of countries (31 countries, 352 papers), followed by Asia (20, 141), America (8, 59), Oceania (2, 13) and Africa (4, 11).

3.1.3. Featured Authors (RQ2)

This analysis provides information on the authors who have generated knowledge [174]; specifically, 947 authors have participated in 396 articles in this field of study. Table 1 shows the top 10 of the most productive authors. Alberto Di Minin stands out with his contributions on topics that include the use of computer science in OI [169,170,175] and others of a general nature in the same subject. The most influential author is Wim Vanhaverbeke for his contributions on OI together with other researchers in studies on external knowledge acquisition and challenges in SME management [29,55,176], on OI practices [31] and on stakeholders [144].

Table 1. Top 10 most productive authors.

Author	Country	Affiliation	Intellectual Structure		Global Publication		HI
			AR	CIT	AR	CIT	
Di Minin A.	Italy	Sant'Anna Scuola Universitaria Superiore Pisa	8	137	65	1118	20
Santoro G.	Italy	Università degli Studi di Torino	7	332	46	1640	18
Yun J.H.J.	South Korea	Daegu Gyeongbuk Institute of Science and Technology	7	239	55	1806	22
Vanhaverbeke W.	United Kingdom	Surrey Business School	6	1834	92	6558	30
Del Giudice M.	Italy	Sapienza Università di Roma	5	410	118	3612	33
Scuotto V.	France	Pôle Universitaire Léonard De Vinci	5	406	50	1392	20
Spithoven A.	Belgium	Universiteit Gent	4	851	31	1303	15
Carayannis E.G.	United States	GW School of Business	4	171	263	5545	38
Ahn J.M.	South Korea	Korea University	4	140	17	300	8
Bogers M.	Netherlands	Technische Universiteit Eindhoven	4	117	63	4130	22

AR = Articles; CIT = Citations; HI = H-index.

Table 1 shows that three of the top 10 authors are from Italy, corroborating the importance of this country in this field of study. Unfortunately, the two prominent authors, Alberto Di Minin and Gabriele Santoro, do not have publications in common on this topic. However, their studies cover similar issues, e.g., proclivity and engagement [3,27,177,178], big data for OI [166,169], dynamics of knowledge [170,175,179], innovation practices [171,180–182] and innovation strategies [155,169]. Meanwhile, JinHyo Joseph Yun has published articles on sustainable growth [183,184], R&D investment [185], OI adoption [186] and knowledge cities [187]. In addition, Gabriel Santoro and JinHyo Joseph Yun share the study area of entrepreneurship theory in OI [142,177,188,189].

3.1.4. Contributions by Journal (RQ2)

This analysis provides an overview of the various disciplines that make up the intellectual structure [190] of OI in SMEs. One hundred and eighty-two journals formed this field of study. Table 2 shows the top 10 journals with the highest number of publications, where the *Journal of Open Innovation: Technology, Market, and Complexity* has the highest number of contributions (24). In this Journal, the most cited article (34) is by JinHyo Joseph Yun, Eui Seob Jeong and JeongHoYun Yang. The authors explored the process of the knowledge-based urbanization of four Korean cities. They concluded that if SMEs reinforced OI, it would be a source of knowledge-based urbanization and lead to the economic development of a knowledge city [187]. The second and third positions come to the journals *Sustainability (Switzerland)* and *Technological Forecasting and Social Change*, both Q1 quartile, the latter of which has the highest value in SJR. Additionally, the *Journal of Business Research*, despite being last in the table, shows the highest H-Index. Half of the journals considered in Table 2 belong to the United Kingdom.

Table 2. Top 10 journals with the highest number of publications.

Rank	Journal	AT	%	HI	SJR
1	*Journal of Open Innovation: Technology, Market, and Complexity*	24	6.06%	22	0.46
2	*Sustainability (Switzerland)*	14	3.54%	85	0.61
3	*Technological Forecasting and Social Change*	14	3.54%	117	2.23
4	*European Journal of Innovation Management*	12	3.03%	63	0.78
5	*International Journal of Innovation Management*	11	2.78%	44	0.57
6	*Technology Analysis and Strategic Management*	9	2.27%	68	0.76
7	*Technovation*	9	2.27%	130	2.30
8	*Journal of Knowledge Management*	8	2.02%	113	1.84
9	*Journal of Small Business Management*	8	2.02%	112	1.68
10	*Journal of Business Research*	7	1.77%	195	2.05

AT = Articles; % = Percentage of contribution; HI = H-Index; SJR = SCImago Journal Rank.

3.1.5. Most Cited Documents (RQ3)

To evaluate an academic field, it is necessary to consider the citations obtained by the papers published on the subject [191]. Consequently, the scientific outputs relating to open innovation and SMEs include 396 articles with 9766 citations. Table 3 shows the top 10 most–cited papers on this topic, representing 39.6% of the total; also, they have more than 150 citations. These articles examine different facets of open innovation in SMEs, such as OI practices [29,31], proposals and strategies [43,46,55], innovation performance [9], absorptive capacity [23,165] and knowledge management capability [57]. Similarly, it is necessary to note that eight articles were published in British journals, while the remaining two articles are from Dutch journals.

The most cited article is authored by Vareska van de Vrande, Jeroen P.J. de Jong, Wim Vanhaverbeke and Maurice de Rochemont (2009) and published in the British journal, *Technovation*. A sample of 605 innovative Dutch SMEs were investigated for the incidence and trend of applying open innovation practices. First, the authors found that such companies are increasingly interested in adopting OI, including trying to benefit from the initiatives and knowledge of their workers and involving their customers in the innovation process [29]. Secondly, Sungjoo Lee and colleagues published a paper in the Dutch journal, *Research Policy*, to propose an intermediated network model. They concluded that networking effectively assists SMEs in their open innovation adoption process [43]. Finally, the third most cited paper is by Vinit Parida, Mats Westerberg and Johan Frishammar, and is published in the *Journal of Small Business Management* from the United Kingdom. They investigate the effects of four inbound OI activities (technology scouting, horizontal technology, vertical technology collaboration and technology sourcing) on innovation performance using a sample of 252 high-tech SMEs [9].

Table 3. Most cited articles.

Rank	Author		Article	Journal	CIT
1	van de Vrande et al. (2009)	[29]	Open innovation in SMEs: Trends, motives and management challenges	*Technovation*	1180
2	Lee et al. (2010)	[43]	Open innovation in SMEs—An intermediated network model	*Research Policy*	753
3	Parida et al. (2012)	[9]	Inbound Open Innovation Activities in High-Tech SMEs: The Impact on Innovation Performance	*Journal of Small Business Management*	397
4	Brunswicker y Vanhaverbeke (2015)	[55]	Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators	*Journal of Small Business Management*	317
5	Spithoven et al. (2013)	[31]	Open innovation practices in SMEs and large enterprises	*Small Business Economics*	268
6	Spithoven et al. (2010)	[23]	Building absorptive capacity to organise inbound open innovation in traditional industries	*Technovation*	253
7	Spithoven et al. (2011)	[23]	Building absorptive capacity to organise inbound open innovation in traditional industries	*Technovation*	228
8	Bianchi et al. (2010)	[46]	Enabling open innovation in small- and medium-sized enterprises: How to find alternative applications for your technologies	*R&D Management*	162
9	Scuotto, Del Giudice, Bresciani, et al. (2017)	[165]	Knowledge-driven preferences in informal inbound open innovation modes. An explorative view on small to medium enterprises	*Journal of Knowledge Management*	156
10	Martinez-Conesa et al. (2017)	[57]	On the path towards open innovation: assessing the role of knowledge management capability and environmental dynamism in SMEs	*Journal of Knowledge Management*	153

CIT= Citations.

3.2. Bibliometric Mapping Analysis

VOSviewer was used to perform the bibliometric mapping. This software uses a technique created by its developers called VOS (visualization of similarities). This technique visualises bibliometric maps better than other software by using multidimensional scaling [192,193]. The process of the construction of each bibliometric map follows three steps: (i) calculate a similarity matrix derived from the co-occurrence matrix, (ii) apply the VOS technique to the similarity matrix, and (iii) translate, rotate and reflect the map [98,194]. The VOS mapping technique constructs a two-dimensional map by minimising the weighted sum of the squared Euclidean distances between all pairs of elements. Therefore, the more similarity between two nodes, the stronger the force of attraction between the nodes [195]. Furthermore, it restricts the average distance between two elements to be equal to 1 to avoid visualisations where all elements have the same location [193,194].

3.2.1. Co-Occurrence Author Keyword Network (RQ4)

The visualization of the study area characterizes this analysis through a semantic visual map that allows an observation of its intellectual structure, development and relevant topics [77,101,196]. Figure 4 shows the co-occurrence network of author keywords, in which there are 41 nodes (relevant topics) and seven clusters (the groupings of nodes of the same colour represent research topics). We constructed the illustration using VOSviewer software and 764 keywords, where 41 co-occurred at least five times.

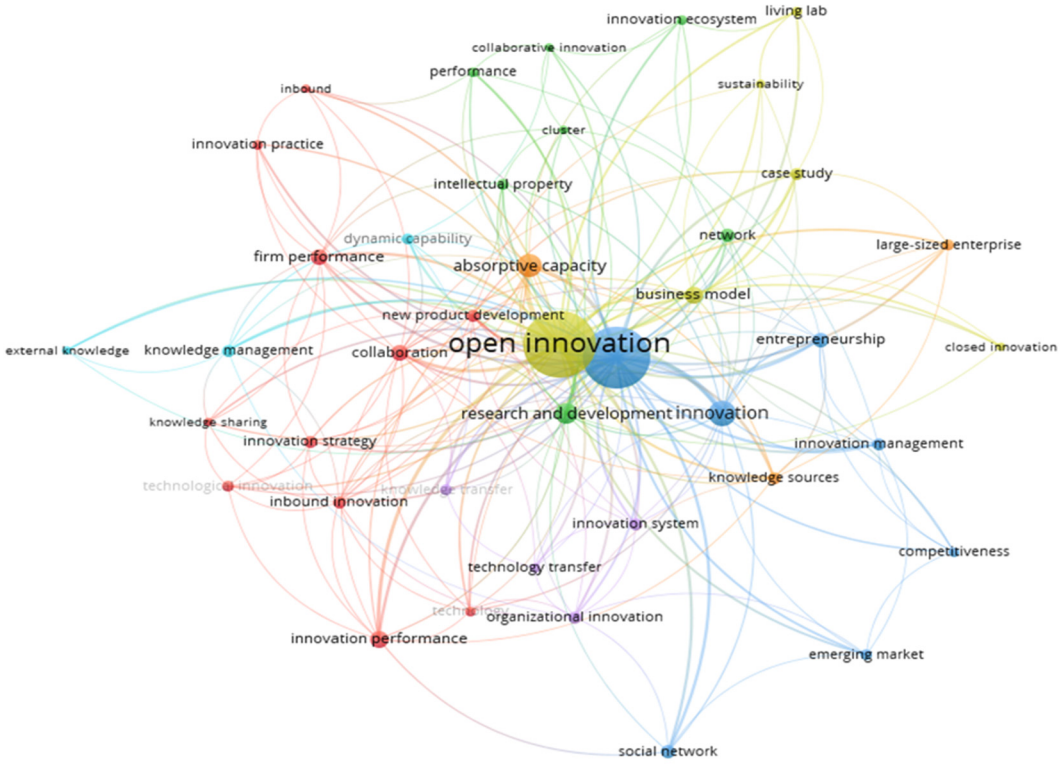

Figure 4. Visualization of co-occurrence author keyword network.

Cluster 1 (red colour), "*Innovation and Firm Performance*", comprises 11 nodes with 104 occurrences, with the terms *innovation performance* and *firm performance* standing out. The papers found in this cluster present relevant information on OI and SME performance. Some researchers have studied innovation performance with entrepreneurial orientation [197], learning strategies [198], organisational sustainability [199] and networking [153,200]. Other authors consider firm performance as a function of cooperation between economic actors (competitors and external firms) [60,148,151], the development of a network structure [201], sustainability [202] and proactivity in innovation [59].

Cluster 2 (green colour), "*R&D Network*", consists of seven nodes with 67 occurrences. This cluster examines the involvement in research and development (R&D) of external knowledge networks that applied OI strategies [52,127,203]. In this context, the effects of collaboration on R&D performance have been considered [204–206]. Therefore, the most relevant keywords in this group are *research and development* and *network*.

Cluster 3 (blue colour), "*SMEs and business management*", consists of seven nodes, as shown in Figure 4. This cluster is the third research area in which the prominent topic is small and medium-sized enterprises (SMEs), with 216 occurrences. This cluster presents studies that relate SMEs to business management issues in subjects that include OI [29,31,43,54,165], entrepreneurship [176,207,208] and social networks [129,209,210].

Cluster 4 (yellow colour), "*Open Innovation and Business model*", is in the centre of Figure 4; it includes six nodes, highlighting the terms *open innovation* and *business model*. This cluster focuses on innovation in business models as an alternative to improve company performance [120,140,183]. Likewise, it includes the transformation of these models with digital technologies [123,211] and their operation in networks [122,212].

Cluster 5 (purple colour) is "*Knowledge Transfer and Organizational Innovation*". This cluster shows the role of knowledge and technology transfer in SME innovation systems [213–215]. This knowledge transfer involves various stakeholders, such as universities and research centres [118,207], and the support of organizational innovation in OI activities [111,216].

Cluster 6 (sky-blue colour), "*Knowledge Management and Dynamic capabilities*", highlights the same named node. This cluster considers studies on the knowledge management capacity of SMEs [57,217], employing absorptive capacities [218] and dynamic capabilities [138,219].

Cluster 7 (orange colour), "*Absorptive Capacity*", is a smaller cluster with three nodes, where the central node gives the cluster its name. This node is close to the open innovation and SMEs core nodes, which shows that it is a capacity developed in this business context (see Figure 4). Studies on this capacity in this cluster examine the absorption of external knowledge [23], especially in inter-firm networks [132,220].

3.2.2. Co-Citation Analysis (RQ5)

This analysis is the most widely used in bibliometric studies, as it allows us to explore the existing relationships between reference documents (the knowledge base). Furthermore, its purpose is to understand the fundamental themes of the field of study, revealing schools of thought or paradigm shifts [66,77,221]. Co-citation is the frequency with which two papers are co-cited by a third paper [77,221,222].

Author Co-Citation Analysis (ACA)

Howard White and Belver Griffith in 1981 proposed this analysis, arguing that if two authors are cited in several documents, it is very likely that they share the same field of research [222–224]. This analysis allows us to explore which authors have been co-cited and which form the knowledge base (reference documents) of the intellectual structure studied [69]. Figure 5 shows the author co-citation network, constructed with the VOSviewer software, grouping the reference authors using the similarity visualisation mapping technique [225]. The nodes represent the authors, which together (in a cluster) can represent topics, specialisations or schools of thought. In Figure 5, we observe a uniform structure formed of four clusters and 334 authors (nodes), elements that make up the knowledge base and have more than 20 co-citations.

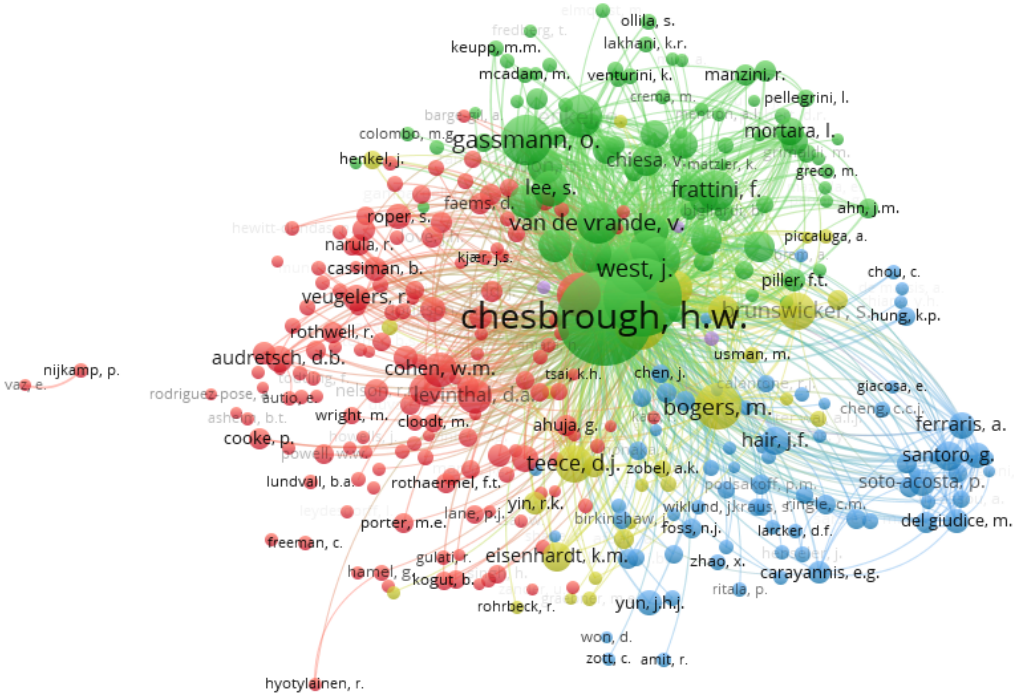

Figure 5. Visualization of author co-citation network.

Cluster 1 (red colour), "*External Knowledge*", comprises 145 authors. This cluster encompasses relevant topics concerning the factors affecting the use of external knowledge during the innovation and development process. Keld Laursen, with 256 co-citations, leads

the group, presenting related studies on the breadth, depth and scope of existing knowledge search [226,227]. Cohen (163) and Daniel A. Levinthal (157) presented studies on the role of R&D in enhancing the firm's ability to assimilate and exploit external knowledge [228], giving rise to the concept of firms' absorptive capacities [229]. Finally, Erik Von Hippel (134) exhibits studies about the lead-user method that has been used under a networking approach so that the firm can take advantage of external knowledge and transform it [230–232].

Cluster 2 (green colour), "*Exploring Open Innovation*", is in the middle, with 83 authors who have pioneered and specialised in the study of open innovation. In this group is Henry Chesbrough (1189 co-citations), who was the originator of the concept of open innovation and who in subsequent works has deepened the theory with individual contributions [1,233] and in collaboration with Wim Vanhaverbeke (809), Joel West (362), Oliver Gassmann (344) and Ellen Enkel (235) [4,5,10,33]. Other scholars have continued the same line of OI development, such as Ulrich Lichtenthaler (254), Vareska Van de Vrande (242), Jeroen P.J. De Jong (195), Maurice De Rochemont (163) and Eelko K.R.E. Huizingh (105) [6,7,29,234–237].

Cluster 3 (blue colour), "*Knowledge Management and Transfer*", presents two groupings of nodes on the left and right side of the cluster (Figure 5). The right section shows authors who considered applications of OI activities: Gabriele Santoro (116), Pedro Soto-Acosta (94), Alberto Ferraris (91), Stefano Bresciani (86), Manlio Del Giudice (79), Elias George Carayannis (66), Veronica Scuotto (59), Simona Popa (54), Isabel Martinez-Conesa (51), Demetris Vrontis (50), Alkis Thrassou (39) and Luca Dezi (32). These authors work in areas that include knowledge management [57,165,238,239] and knowledge exchange and sharing [166,240]. Finally, on the left side, some authors present statistical methods for the reliability and validation of the results of the proposed models, such as Joseph Hair (101), Rolph Anderson (54), Christian Ringle (57), Marko Sarstedt (53) and William Black (51) [241–246].

Cluster 4 (yellow colour), "*Practices and Capabilities on Innovation*", made up of 30 authors, includes those focused on exploiting innovation that can serve as a guide to generate competitive advantages. Ammon Salter (360) stands out in this cluster [5,227,247]. Furthermore, to this cluster belongs authors, such as Marcel Bogers (278) and Sabine Brunswicker (185), who have conducted research together with Chesbrough on OI practices [2,248,249]. It also includes Linus Dahlander (169) [44,250] and Nadine Roijakkers (126), who delved into OI issues and their practices [31,251]. Other authors, such as David J. Teece (189) and Kathleen M. Eisenhardt (117), have contributed to the development of dynamic capabilities [252–255].

Cluster 5 (purple colour), "*External Innovation Strategy*", has three authors, Jin Chen (32), Jose Luis Hervas-Oliver (25) and Priit Vahter (22), whose publications are related to innovation strategies through external resources (outside-in) and their implications for the firm as a result of their application [156,256,257]. Finally, it is noteworthy that, on average, authors are co-cited with other scholars in the same cluster 10 times.

Journal Co-Citation Analysis (JCA)

This analysis considers the similarity of journals in terms of the citation patterns received, where two journals are cited jointly by several documents related to each other [258]. This analysis allows us to understand the structures of academic specialisations [259].

Figure 6 shows this network of co-citations of journals, visualising the various journals (nodes) and their connections. This structure has six clusters including the 91 journals with at least 20 citations.

Cluster 1 (red colour), "*Business, Knowledge and Technology*", represents 55 journals with 4587 citations. In this group, we can distinguish the *Journal of Small Business Management* (the United Kingdom, 376 citations), *Journal of Business Research* (the United States, 309), *Technological Forecasting and Social Change* (the United States, 309), *Journal of Knowledge Management* (the United Kingdom, 270) and *European Journal of Innovation Management* (the United Kingdom, 241), among others.

Cluster 2 (green colour), *"Policies and SMEs Management"*, comprises 24 journals with 3994 citations. These journals stand out for their multidisciplinary publications, emphasising management and economics relevance. In this group are journals, such as

Research Policy (the Netherlands, 1787), *Small Business Economics* (the Netherlands, 373), *Administrative Science Quarterly* (the United States, 282) and *International Small Business Journal* (the United Kingdom, 223), among others.

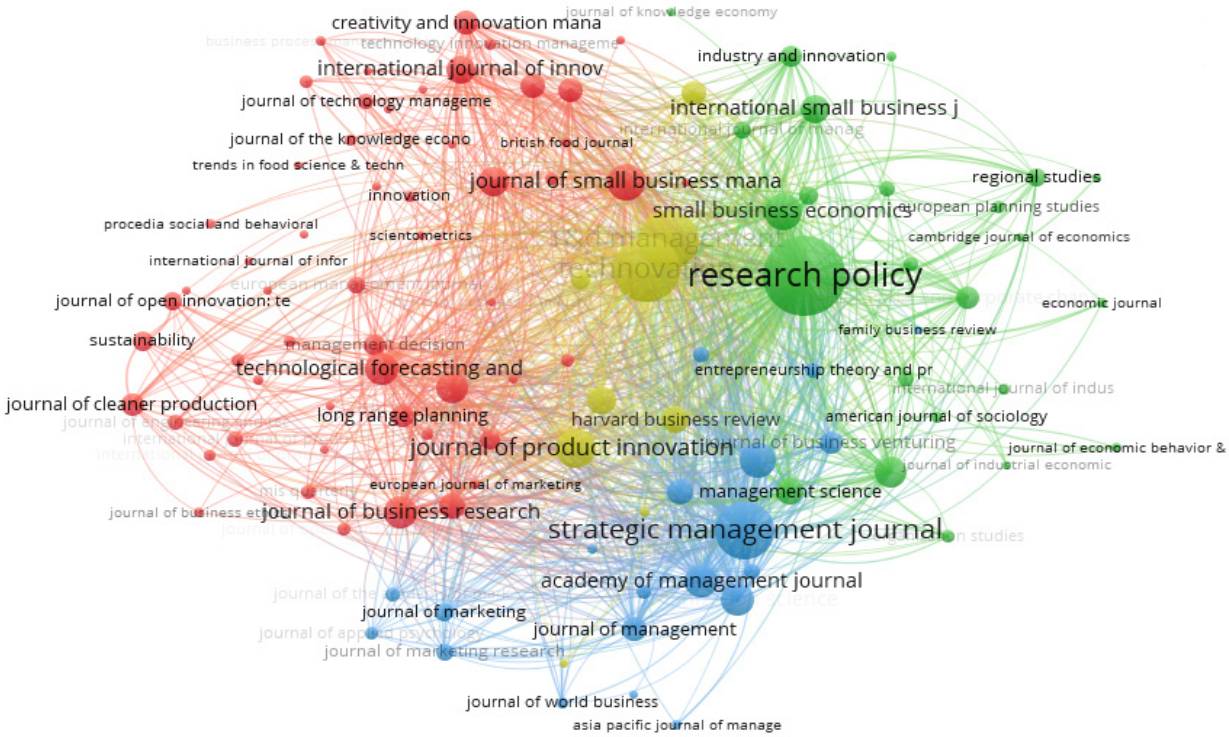

Figure 6. Visualization of journal co-citation network.

Cluster 3 (blue colour), "*Business Research*", consists of 20 journals with 3096 citations. Usually, the journals that belong to this group publishes articles that seek to explore the various areas that concern organizations, such as strategic management, business policy, processes and technologies. In this cluster, the following stand out: *Strategic Management Journal* (the United Kingdom, 924), *Academy of Management Review* (the United States, 340), *Academy of Management Journal* (the United States, 308) and *Organization Science* (the United States, 292), among other.

Cluster 4 (yellow colour), "*Management*", consists of nine journals with 3357 citations. These journals often feature articles contributing to research and development management (R&D). As an example, these journals are *Technovation* (the United Kingdom, 1168), *R&D Management* (the United Kingdom, 968), *Journal of Product Innovation Management* (the United Kingdom, 453) and *California Management Review* (the United States, 221).

4. Discussion

The study of open innovation in small and medium-sized enterprises (SMEs) began more than 15 years ago, with a steady increase in scientific outputs due to the contribution of 65 countries spread over five continents, but mostly from developed countries (Figure 3). The United Kingdom, Italy and Spain stand out in terms of publications. Unsurprisingly, the UK leads in scientific output, with its large contribution from 29 countries. In addition, it has policies that encourage industry–university collaboration to facilitate product, service or process innovation in SMEs [260], as well as access to open data through the UK Innovation Survey (UKIS) [261].

In the period 2007–2010, authors Wim Vanhaverbeke, Vareska Van de Vrande, Byungun Yoon, who have high impact, together with other researchers, presented exploratory studies that addressed the first analyses of OI management in SMEs [29,111], taking into account

one of the most primitive of OI activities, which is the use of networks and partnerships in the innovation process [108,112,113].

In 2011–2020, researchers Alberto Di Minin, Gabriele Santoro and JinHyo Joseph Yun stood out for their academic contributions (Table 1). However, the heterogeneity of research purposes marks this period with the abundance of research that accounted for 80% of the scientific production (Figure 2). The increase could be explained by the apogee of regional innovation systems, specifically in the urban environment [262], as well as the adaptation to Industry 4.0 [263] and the role of innovation in recent years [264]. Therefore, this allowed a deepening of OI practices, strategies, sources and their consequent benefits to firms [9,55,166,169,186]. Additionally, there is some recent research on formulating and validating proposals to implement specific OI activities to provide insightful information to the business world [265,266]. Therefore, we expect further development in this study in the coming years.

The analysis of the intellectual structure involves the use of three scientific maps:

Firstly, in the analysis of the co-occurrence of the authors' keywords (Figure 4), firm and innovation performance in SMEs (red cluster) under a business management context (blue cluster) were the most studied topics in open innovation and business models (yellow cluster) [9,120,127,166,267]. Likewise, substantial literature has specialised in analysing the practice of networks for collaboration activities (green cluster) [43,268]. This, in turn, has given way to the analysis of knowledge transfer and management (purple and sky-blue clusters) [145,162,214], absorptive capacities (orange cluster) [269,270], and knowledge management and dynamic capabilities (sky-blue cluster) [201,219].

Secondly, the co-citation analysis of authors allows us to observe the inter-connections that different authors have in the area of open innovation in SMEs (Figure 5). For example, authors, such as Henry Chesbrough and Wim Vanhaverbeke (green cluster), have been pioneers in open innovation studies. They have maintained their writings by exploring and expanding this topic [33,271]. Hence, the level of co-citation between authors in this cluster is very high compared to the others, given that they represent the basis of the intellectual structure. Furthermore, researchers, such as Alberto Ferraris, Manlio Del Giudice and Luca Dezi (blue cluster), have collaborated in the area of study related to knowledge management and transfer [272–274]. Meanwhile, scholars, such as Jin Chen, Priit Vahter and Jose Luis Hervas-Oliver (purple cluster), have contributed to external innovation strategies [256,275,276]. Similarly, as explained above, there is a vast literature on OI where authors have used various frameworks, such as dynamic capabilities by David J. Teece (yellow cluster) [252–254] and absorptive capacity by Wesley M. Cohen and Daniel A. Levinthal (red cluster) [229].

Thirdly, the journal co-citation analysis (Figure 6) shows that the red cluster comprises the most significant number of journals because these journals deal with the most analysed general areas concerning OI in terms of knowledge, innovation and technology management. Meanwhile, despite having few journals, the rest of the clusters (yellow, blue and green) are characterised by their high impact on business management.

Finally, this study analyses the whole intellectual structure of open innovation in SMEs and its issues of interest, such as its practices and activities, the process of transition to an open model, the effects of its application and proposals for strategies to exploit its benefits.

5. Conclusions

This study aimed to evaluate the field structure of open innovation in small and medium-sized enterprises (SMEs) through a bibliometric analysis using the Scopus database and VOSviewer software. This research reveals a scientific output with a positive growth trend reflected in the collaboration of 65 countries, 947 authors and 182 journals. This fact implies a high performance in the field of study.

The most productive contributors are (i) authors, Alberto Di Minin and Gabriele Santoro, (ii) countries, the United Kingdom and Italy and (iii) journals, *The Journal of Open Innovation: Technology, Market, and Complexity* and *Sustainability*. The most influential con-

tributors (based on the number of citations) are (i) author, Wim Vanhaverbeke, (ii) country, the United Kingdom and (iii) journal, *Technovation*. Furthermore, the most influential article (based on the number of citations) is "Open innovation in SMEs: Trends, motives and management challenges" by van de Vrande and colleagues (2009).

On the other hand, the bibliometric mapping analysis provided insights into the various areas and networks of researchers that make up the intellectual structure of the study of open innovation in SMEs.

The co-occurrence author keyword analysis exhibits seven themes associated with this intellectual structure: firm performance, R&D networks, business management, business models, capacities and knowledge transfer. The knowledge base lies (author co-citation) in researchers, such as H. Chesbrough, W. Vanhaverbeke, J. West, A. Salter and O. Gassmann, and for other fields with authors, such as Wesley M. Cohen and Daniel A. Levinthal (absorptive capacity), David J. Teece and Kathleen M. Eisenhardt (dynamic capabilities). The research activity relies (journal co-citation) on journals related to management, technology and business management.

This study is a contribution to the academic world by exploring the intellectual structure of OI in SMEs due to: (i) the ease of access to scientific knowledge by obtaining information on the authors of the different topics and related subjects of study; (ii) the possibility of forming collaborative networks by knowing the different researchers involved; and (iii) acting a guide for novice researchers to learn about this intellectual structure in broad terms.

6. Limitations and Future Research Directions

This study has some limitations. First, there is a bias in bibliometric analysis because sometimes the citation index measures quality. However, the fact that an author is prolific persuades other scholars to cite this author without reading the article. Secondly, selecting the Scopus database rather than other recognised databases, such as Web of Science and Dimensions, can miss some documents. Thirdly, the VOSviewer software does not allow the use of a combined database.

Research on OI in SMEs is recent and has grown rapidly in recent years; however, there is a need to explore the possibility of expanding research in the area. The following are some research gaps that future studies could take into account:

1. *Literature review studies.* Few studies address this topic [61–63] or consider it from the perspective of young SMEs [36]. However, advances in this field in the last five years (2017–2021) account for 64% of scientific outputs, so new review studies are needed. Furthermore, scarce research addresses its entire intellectual structure [65], making it necessary to broaden its coverage by considering other databases and types of documents.
2. *Studies in developing countries (single or multi-country).* Most research on OI in SMEs are in developed countries, whilst few studies are in developing countries [161]. These studies in developed countries cannot necessarily be replicated in developing countries due to socio-economic, cultural and political differences. Therefore, there is an open space for evaluation in this context.
3. *Sectoral (specific or multi-sectoral) studies.* There are new topics that require further studies in specific or multiple economic sectors, such as:
    - Sustainability models oriented towards open innovation and their follow-up [157, 159,277].
    - Entrepreneurship and multi-level enterprises [164].
    - Social media and its effects on business innovation [197].
    - Digitalisation in SME business management [168].
    - Knowledge leverage capability in OI [278].
    - Business to business (B2B) open innovation, especially post-pandemic [279].
    - Innovation typologies and strategies in a regional context [156].
    - Industry 4.0 [280].

4. *Studies on the work environment in the implementation of OI.*
   - Worker personality, commitment and involvement in OI activities [89,154].
   - Involvement of workers and consumers as informants [158].
5. *Studies on the relationship of managers/owners in the application of OI.* Most research does not consider the gender, age, education, experience, culture and ethnicity of this management group. Therefore, it is necessary to study these characteristics to have a holistic approach of the managers and their relationships with the OI.

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