



2nd AISPI International Biennial Conference on Harnessing Science, Technology and Innovation
for Inclusive Development in an Uncertain Future, 2021

Systematic Review of Open Eco-Innovation Research Landscape in the Industrial Sector

Maruf Sanni^{1,2*} and Elena Verdolini^{1,3}

¹RFF-CMCC European Institute on Economics and the Environment, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy.

²National Centre for Technology Management, Federal Ministry of Science and Technology, Ile-Ife.

³Department of Law, University of Brescia, Italy.

*Corresponding author's email address: maruf.sanni@eiee.org

Abstract

Open eco-innovation (OE) studies is an emerging research domain of potential contributions to sustainable industrial development. Openness benefits environmentally friendly firms by strengthening their relationships with environmentally responsible external partners thereby ingraining them in the social fabric of environmental innovation systems. Exploratory, bibliometric and network visualization mapping techniques were applied with the aim of synthesizing and characterizing the available knowledge in the field of open eco-innovation research. The systematic review is based on a sample of 102 articles published over the period of 1990 and 2019, which have been retrieved through a bibliometric search in Scopus. Results show that the literature on OE has increased significantly in the last eight years and this trend is likely to continue. It was noted that OE research landscape is at the acceleration phase. The results also indicate that both analytic and synthetic modes of external knowledge sourcing are complementary. The study unraveled clusters of fields of studies that could represent theoretical perspectives with which theory of open eco-innovation could be built. This paper contributes to the literature on open innovation by tracing the growth trajectory and mapping the theoretical base of the OE research field while pointing to new OE themes.

Keywords: Open Eco-innovation; External Knowledge Sourcing; Bibliometric Technique; Systematic Literature Review; Open Innovation; Co-citation Analysis

1. Introduction

The narrow view of innovation as mainly dependent on internal capability of firms is gradually becoming less important as latest literature suggests that more firms are consistently acquiring external knowledge in combination with intramural R&D to implement innovation (Cainelli *et al.*, 2015; Cruz-González *et al.*, 2015; de Marchi & Grandinetti, 2013; Ghisetti *et al.*, 2015, 2021; Veronica *et al.*, 2019). This concept sits within the paradigm of open innovation, conceptualized by Chesbrough (2003) to describe and grasp the essence of combining knowledge sourcing strategies. According to this concept, organizations broaden their innovation efforts beyond their own boundaries by exploiting inbound and outbound knowledge flows to improve innovation success (Chesbrough, 2006).

In the specific research domain of environmental economics, the issue of sources of information and knowledge used by eco-innovative firms is of utmost importance (González-Moreno *et al.*, 2019; Horbach *et al.*, 2013). To implement eco-innovation is a complex endeavor that requires access to variety of knowledge and skills that are different from the conventional knowledge base for the mainstream innovation. Many authors have focused on this issue with more attention paid to ‘double externality problem’ and determinants of eco-innovation (Avellaneda-Rivera *et al.*, 2019; Cristina Díaz-García *et al.*, 2015; De Marchi, 2012; de Marchi & Grandinetti, 2013; Rennings, 2000). There is usually a disincentive to invest in eco-innovation because the value created by an eco-innovative firm often accrues to other firms due to knowledge spillovers. This externality and many others create market failures which have induced the need for regulatory policies to encourage eco-innovators (Rennings, 2000). More importantly, issues such as these have made access to diverse source of knowledge to be more important for eco-innovation than mainstream innovations (de Marchi & Grandinetti, 2013). Based on these facts, it is clear that external sources of knowledge are an important driver of eco-innovation, and one that should be considered in environmental innovation studies (Jeong & Ko, 2016).

After an extensive review of literature, no other study was found to have carried out extensive systematic reviews and analyses of eco-innovation performance with a view to mapping the state-of-the-art of OE. The extant literature in this area are often too general (Pham *et al.*, 2019), specific to particular sectors (Avellaneda-Rivera *et al.*, 2019; Sáez-Martínez *et al.*, 2016), or based purely on unsystematic review of the literature (Cristina Díaz-García *et al.*, 2015). This study aims to fill this gap in the literature by examining how the concept of OE has evolved around the main philosophy of eco-innovation and to see if there are any potential opportunities for theory development. Therefore, the main objective of this study is to present a critical and systematic review of literature on external knowledge sourcing for eco-innovation through the concept of OE. The study highlights the existing research gaps and suggests future directions for advancement of this particular research domain. To satisfy this objective, the following research questions (RQ) are presented:

RQ1: What is the growth trajectory of OE literature?

RQ2: What are the key geographical and institutional contexts in which OE has been studied?

RQ3: What are the theoretical underpinnings supporting OE research domain?

The rest of this paper is structured as follows. Section 2 reviews existing literature; Section 3 explains the methods employed to systematically review the papers selected from Scopus database; section 4 presents the findings and discussions related to the three research questions; and Section 5 highlights key findings, the limitation of the study and states the existing research gaps.

2. Literature Review

Knowledge search mode is defined as the firm’s problem-solving strategies through which firm acquires external knowledge (Katila & Ahuja, 2002; Laursen & Salter, 2006). Firms often lack cognitive proximity which is needed to expand their existing knowledge base (Boschma, 2005) to make successful implementation of eco-innovation possible (De Marchi, 2012). As a result of this, firms may have to look for alternatives for production processes, inputs and/or materials that are not necessarily within their core

competence which further accentuates the challenges in understanding and implementing new processes or inputs (Teece *et al.*, 1997). Eco-innovation requires knowledge inputs from many and diverse sources (Oltra & Saint Jean, 2009; Rennings & Rammer, 2009). Unfortunately, many studies have overlooked the relevance of external knowledge sourcing mode for eco-innovation (Horbach *et al.*, 2013).

Laestadius (1998) categorized knowledge base into two: ‘analytical’ and ‘synthetic’. An analytical knowledge base places high value on scientific knowledge and systematic development of products and processes (Marzucchi & Montresor, 2016). Firms that depend on this kind of knowledge base often have their own R&D departments. In the case of a synthetic knowledge base, most of the firms using this category of knowledge innovate by combining and applying existing knowledge to provide solutions to specific market frictions while interacting with customers and suppliers. There is also the third category of knowledge base termed ‘symbolic’ (Martin & Moodysson, 2011). Here, the innovation is not so much about the creation of products or services. Rather, it is the impression that the firms attempt to create in the minds of the consumers (see Table 1).

Table 1: knowledge bases involved in innovation process

	Analytical	Synthetic	Symbolic
Rationale for knowledge creation	Reveal the mechanisms defining the workings of data-enabled operating systems	Control the display (on a computer monitor) that allows the user to interact with the system	Differentiate and enhance the user experience of portable devices (e.g. mobile phones)
Modes of knowledge creation	Research collaboration between firms (R&D department) and knowledge institutions, interpretation of existing systems by unravelling their structures and mechanisms	Interactive learning with clients and suppliers, learning by doing, experimentation, trial and error, computer simulations	Advanced design based on visual experience and artistic skills (creative process)
Sources of knowledge	Dominance of codified knowledge, documentation in patent records, scientific journals, academic conference and workshop proceedings	Dominance of tacit knowledge, more from technical know-how, craftsmanship, and practical skills	Dominance of tacit knowledge, more from technical know-how, craftsmanship, and practical skills
Knowledge characteristics	Importance of scientific knowledge often based on deductive processes and formal models	Importance of applied, problem-related knowledge often through inductive processes; experience based practical/technical knowledge, on-the job training	Knowledge adapted to (territorially confined) cognitive institutions (language, perception etc).
Innovation output	Innovation by creation of new knowledge; more of radical innovation	Innovation by application or novel combination of existing knowledge; mainly incremental innovation	Could either be radical or incremental innovation or both

Source: Authors’ draft, adapted from B. T. Asheim & Gertler (2005; Bjorn Asheim et al. (2007; Bjørn Asheim & Hansen (2009; and Martin & Moodysson (2011)

3. Research Methodology

3.1. Background to the systematic review methodology

This paper followed the systematic review method suggested by (Tranfield *et al.*, 2003), (Halilem, 2010) and (Pham *et al.*, 2019). It also aligned with the review process called PRISMA protocol (Moher *et al.*, 2010). As such, this study is conducted in the following 6 steps:

1. framing explicit research questions;

2. setting inclusion and exclusion criteria to gather documents;
3. searching, locating and identifying studies that meet the inclusion and exclusion criteria; evaluating the quality of the selected studies;
4. data extraction, coding and monitoring progress; and
5. data synthesis/analysis and reporting results.

This article adopts qualitative narrative (exploratory) method for the analysis of synthesis of the literature (Hazarika & Zhang, 2019; Pacheco *et al.*, 2018; Snilstveit *et al.*, 2012). Bibliometric and network visualization mapping techniques were used to gain insights into the emerging research domain. Data processing and coding are conducted in Microsoft Excel, Mendeley and VOSviewer.

3.2. The Systematic Review Protocol

3.2.1 Inclusion and exclusion criteria

One of the first conditions for selecting an article for review in this paper is that it must consider eco-innovation, environmental innovation, low-carbon innovation or green innovation as the main concept and respond to at least one of the three research questions. Eco-innovation is a relatively new field of study (Cristina Díaz-García *et al.*, 2015). However, the concern on the negative impact of human activities on the environment could be said to have started with the Brundtland report when the issue of sustainable development was raised (Brundtland, 1987). Technically, eco-innovation came into scientific literature in the '90s Fussier & James, (1996) and James (1997) defined it as “new products and processes which provide customer and business value but significantly decrease environmental impacts”. As such, the third criterion for inclusion considered only articles published on eco-innovation between 1990 and 2019. This period was chosen because it heralded in the concept of sustainability as a result of great awareness created by sustainable development towards the end of 1990 (Brundtland, 1987; Schubert & Láng, 2005). Therefore, any discourse surrounding OE would not be complete without tracking studies around this period. The fourth criteria involved only online peer-reviewed articles published within the period specified above. This criterion allowed the evaluation of papers that have undergone thorough review process by researchers and experts in the field of environmental sustainability. Conference proceedings as well as journal articles that did not present a description or illustration of how firms source, use, absorb or integrate external knowledge for the implementation of eco-innovation were excluded.

3.2.2. Identifying the appropriate articles

The identification of studies to be included in the systematic review entails two steps:

1. Locating and enlisting studies
2. Selecting articles

Locating and enlisting studies.

In order to locate and select articles that fulfil the criteria, a search mainly across Scopus database was performed. In this review, the analysis was based on this database because it offered a great flexibility, particularly with regard to search terms and citations search. It is also one of the largest abstract and citation databases of peer-reviewed literature. Keywords and search strings that allowed the combination of keywords and their synonyms into logical expressions to incorporate many journals in the field of interest were established for this study (Hazarika & Zhang, 2019). Most of the literature in the area of sustainability often use four different terms to depict innovations that decrease negative impact on the environment: “green”, “eco”, “environmental” and “sustainable”. Majority of researchers use these terms interchangeably, as such this paper considered these four terms as interchangeable and identical (Xavier *et al.*, 2017). Additional search was conducted manually on ResearchGate database. This database afforded the flexibility of contacting authors that are registered in the database directly to share their articles for the purpose of this study. The first search yielded a total of 16,315 journal articles retrieved from Scopus database. It was later reduced to 11, 719 when the search was narrowed down to the disciplines of interest such as Social Sciences”, “Business, Management and Accounting” and “Decision Sciences”

“environmental science”, “energy”, “economics”, “econometrics” and “finance”. In addition to these journals, an additional 52 peer reviewed articles through the search on ResearchGate were retrieved.

Selecting articles

In order to select the relevant literature for the study, Chesbrough’s definition of open innovation was adapted (Chesbrough, 2006). For the purpose of this study open eco-innovation was described as firms’ expansion of innovation efforts beyond their own boundaries by making use of inbound and outbound knowledge flows to enhance eco-innovation success. Therefore, any peer-reviewed articles that examine firms sourcing knowledge strategies or collaborating with external actors such as customers, suppliers, universities, research institutes, consultants, professional associations, formal and informal social networks and so on. to eco-innovate were selected. Selecting the last set of articles for review consisted of two steps. Two-hundred and twenty-two articles were selected in the first round. After the second step, the final sample of 102 selected journal articles were selected. Figure 1 shows the research process for the literature synthesis.

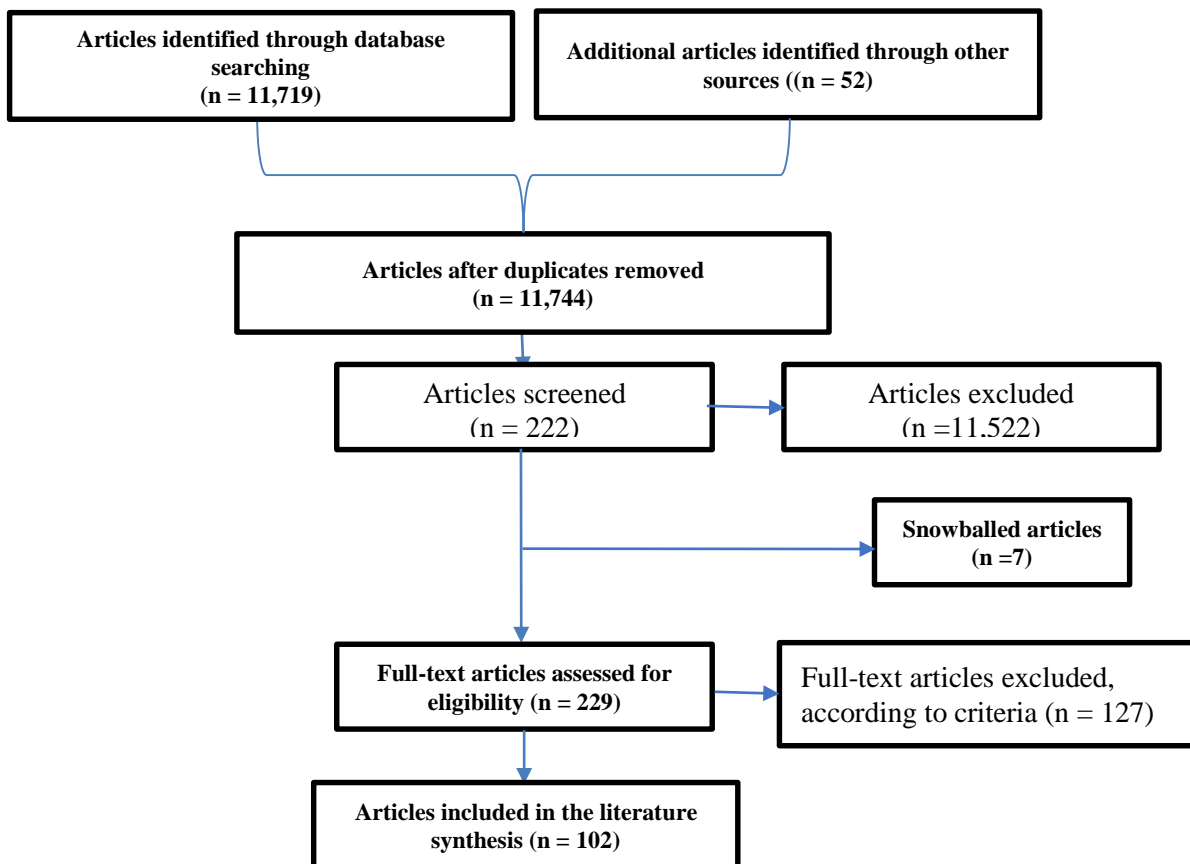


Figure 1: Research process for the literature synthesis

3.3. Data analysis techniques

In order to gain a comprehensive insight into the knowledge base of OE, a bibliometric analysis was conducted. Bibliometric analysis technique is a reliable tool for citation analysis, text and data mining (Nerur *et al.*, 2008). It also permits analysis of trend, evolution, and structure of a particular research field thereby allowing for a detailed understanding of the structure of the knowledge base (Zupic & Čater, 2015). One of the bibliometric techniques that can be used to understand the structure of the knowledge base of a research domain is author co-citation analysis (Falagas *et al.*, 2008; Zupic & Čater, 2015). The use of VOSviewer software to visualize the bibliometric dataset from Scopus was employed (Van Eck & Waltman, 2013). With the aid of VOSviewer, the following analyses which enable the comprehension of the development and trajectory of OE in sustainability study landscape was carried out. These analyses include (Van Eck & Waltman, 2013):

1. citation analysis: the relatedness of items determined based on the number of times the authors cited each other;
2. co-citation analysis: the relatedness of items determined based on the number of times they are cited together;
3. bibliographic coupling by sources and countries.

4. Results And Discussion

4.1 Evolution and main sources of publications

4.1.1. Growth trajectory of OE literature

In a bid to understand the growth trajectory of a research domain when applying bibliometric analysis, four phases of development were conceptualized: start, acceleration, transition and deceleration. The start phase is described as the initial stage of the research domain when scholars are beginning to explore or understand the field. The acceleration phase consists of the period when the research domain becomes popular as a result of better understanding of the concept or an important event took place e.g. Paris agreement, and the pronouncement of sustainable development goals among others. The transition phase denotes when a particular research field becomes matured and it is beginning to give rise to some other popular concepts with capability to evolve or transit to another research domain (e.g. innovation giving rise to open innovation). The deceleration phase begins when scholars start to lose interest in a particular research domain as a result of better alternative or lack of relevance. In this article, two phases from the analysis of OE research landscape based on the conceptualized four phases explained above were recognized. That is, start and acceleration phases. The start phase covered period between 1990 and 2011 (see Figure 2a). The period recorded only 6 articles. The first article in the sample was published in 1999 (Vickers & Cordey-Hayes, 1999) as no article in the Scopus database that directly explored open eco-innovation concept between 1990 and 1998 was found. In the meantime, the interest in the field of OE began to gain prominence in the 2nd phase. It could be seen that the rate of growth was astronomical when compared with the 1st phase. This period covered 2012 till 2019 when 79 articles were produced compared to only 6 articles produced in the 1st phase. Another characteristic of this phase is that the period recorded a lot of citations from scholars indicating an emerging and popular research domain. For instance, the total number of citations recorded during this period amounted to 1706 compared to 402 recorded in the 1st phase (See Figure 2b). In other words, this period recorded 80.93% of the total citations. This phenomenal increase in citation could be said to owe a lot to the publication of seven influential articles: (Cainelli *et al.*, 2015; De Marchi, 2012; de Marchi & Grandinetti, 2013; Ghisetti *et al.*, 2015; Gimenez & Tachizawa, 2012; Kim *et al.*, 2018; Ornetzeder & Rohrer, 2006). These seven articles garnered 53.22% of the total citations during the period of study and it is only a matter of time for the citations to increase as majority of these articles were only published few years ago. The temporal distribution of citation is shown in Figure 2a.

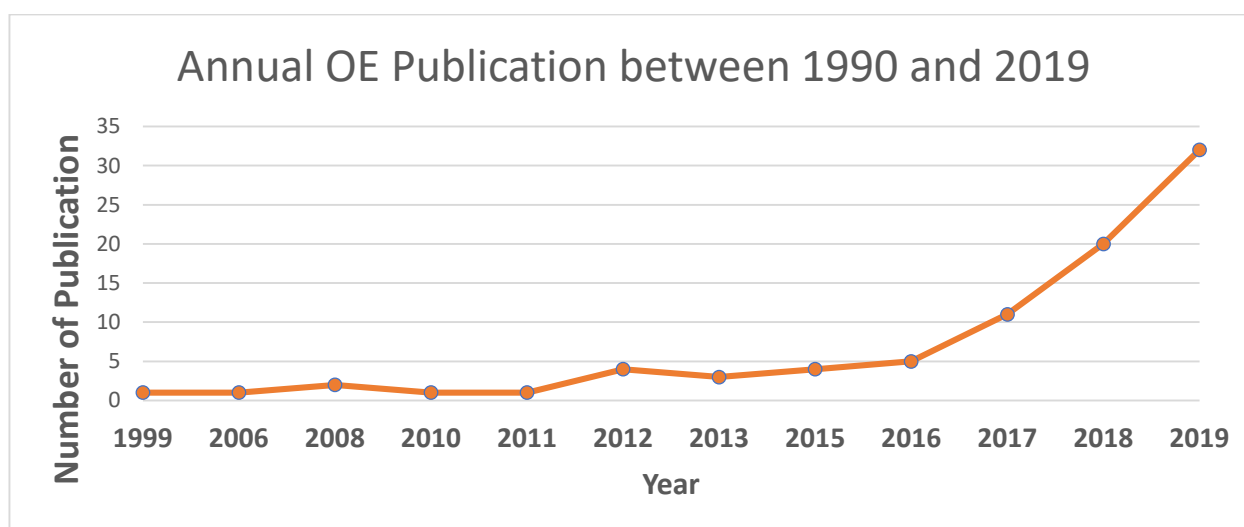


Figure 2a: Temporal variation of publication on OE between 1990 - 2019

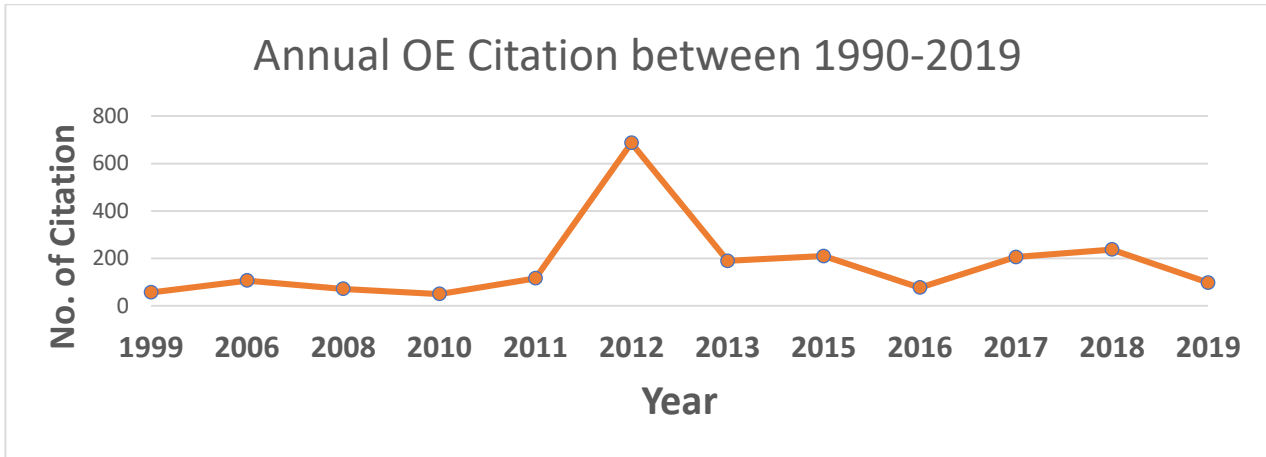


Figure 2b: Annual OE Citation between 1990-2019

4.1.2. The most cited publication/articles

Some of the most cited OE-oriented articles within the study period include Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms (De Marchi, 2012) with well over 343 citations. This is followed by the article, The open eco-innovation mode. An empirical investigation of eleven European countries written by Ghisetti et al. (2015) with 107 citations. A paper, Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms by Cainelliet al. (2015) is also another influential article on OE research landscape. It recorded 91 citations. Other highly cited articles include those written by de Marchi and Grandinetti (2013), Dangelico *et al.* (2013), Klewitz *et al.* (2012) and Marzucchi and Montresor (2017). Majority of these highly cited papers were published in highly-rated journals such as Research Policy (RP), Ecological Economics (EE), Journal of Cleaner Production (JCP), Journal of Knowledge Management (JKM) among others. The visualization network map showing how the highly cited articles are connected to one another is shown in Figure 3. The bigger the node for each article, the higher the number of citations that the particular article has gathered. This figure also reveals connectivity between the new and the old articles. The new articles are indicated mostly by purple and blue nodes while the old articles are indicated mostly by yellow and green nodes. As in many other research fields, some new articles tend to be well connected with the old influential articles suggesting direction of flow of knowledge.



Figure 3: Network map for most cited OE articles during 1990 and 2019

4.1.3. Journal distribution

Analysis in Table 2 shows the leading 10 productive journals in the field of OE between 1990 to 2019. Among the leading 10 productive journals that have the most publications in OE, the number of publications in the top 6 journals accounted for 48.44% of the total (see Table 3). In particular, JCP is the most productive journal with 37 articles accounting for 28.91% of the global total. This is followed by Business Strategy and The Environment (BSE) with 13 articles and EE with 4 publications. Other high impact journals such as RP and Energy Policy (EP) have 3 articles each. Meanwhile, in terms of impact of the articles in each of the journals, articles in JCP have less impact when compared with RP, SCM and EE. For instance, RP, Supply Chain Management (SCM) and EE recorded 150, 138.50 and 60.25 citations per publication compared with 13.65 recorded by JCP.

Bibliometric analysis and visualization of sources of the OE-oriented articles and citations were carried out. The network analysis of the distribution of articles among different types of journals is shown in Figure 4a. In the network visualization map, articles are represented by their labels and by default also by a node. The size of the label and the node of an article are determined by the total number of articles published in a particular journal. The higher the number of the articles, the bigger the label and the node of the journal. At the same time, the color of a journal is determined by the cluster to which the journal belongs. For instance, Figure 4a shows that JCP and BSE do not only belong to same cluster but are also the journals of choice for scholars publishing in the field of OE as they both represent journals with the largest share of articles in OE. Figure 4a also shows that both JCP and BSE are related. Other journals in the same clusters are EE, RP and Business Ethics (BE). Network lines between journals represent links. The distance between two journals in the network visualization map is an indication of their relatedness in terms of co-citation links. Therefore, the closer two journals are sited to each other, the stronger their relatedness (Van Eck & Waltman, 2013).

Table 2: The leading 10 productive journals in OE

Journal	Field of the Journal	TP R		IF	TC	CPP
		TP	(%)			
Journal of Cleaner Production	Environmental science	35	31.82	6.395	469	13.40
Research Policy	STI management	3	2.73	5.425	450	150.00
Journal of Supply Chain Management	Supply Chain Management	2	1.82	4.296	277	138.50
Business Strategy and the Environment	Competitive strategy and environmental management	11	10.00	6.381	183	16.64
Ecological Economics	Ecological Economics	3	2.73	4.281	40	13.33
Energy Policy	energy policy and energy supply	3	2.73	4.88	107	35.67
Journal of knowledge Management	Knowledge Management strategies	1	0.91	4.604	82	82.00
Journal of Product Innovation Management	Business, Management	1	0.91	3.781	76	76.00
European Journal of Innovation Management	Innovation studies	2	1.82	1.793	60	30.00
Technology Analysis and Strategic Management	STI management	1	0.91	1.739	57	57.00

Note: TP: total publications; R (%): ratio of the number of one journal's publications to the total publications; IF: impact factor; TC: total citations; CPP: citations per publication.



Figure 4a: Bibliographical coupling by journal

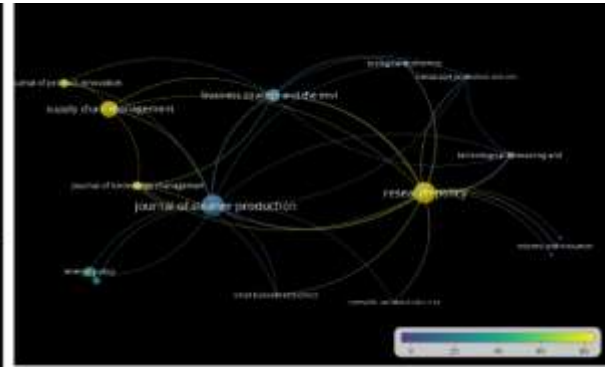


Figure 4b: Bibliographical coupling by citation

Once again, Figure 4b buttresses the point about relative impact of journals like RP, SCM. For instance, RP, SCM and JKM with red nodes recorded an average of 80 citations per article compared with articles published in JCP and BSE which recorded less than an average of 20 citations per article. Analysis of citations per publication (CPP) in table 3 also emphasized this fact. Results in table 3 further show that OE has attracted interests of scholars from various fields including environmental science, science, technology and innovation (STI) management, supply value chain management, ecological economics, energy policy, and knowledge management among others.

4.2. Key geographical and institutional contexts in which OE has been studied

4.2.1. Geographic distribution of OE literature

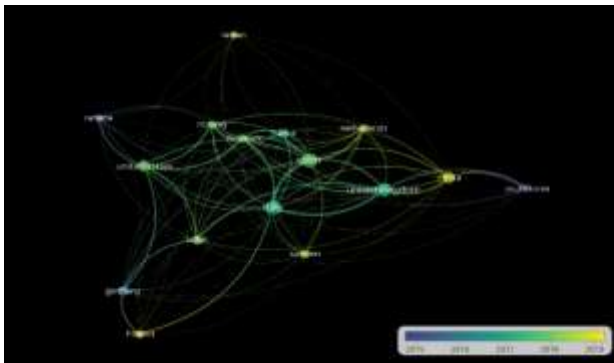
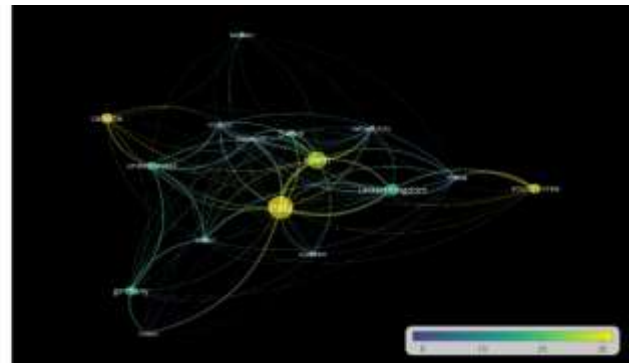
Table 3 shows the top 10 most productive countries in OE literature based on the country where the institution of the author is located. European countries led by Italy (17) and Spain (17) are the most productive countries. These were closely followed by the United Kingdom (15), China (10) and the United States of America (10). In all, 10 leading countries accounted for over 90% of the total knowledge production of OE in the Scopus database within the study period. It is interesting to note that China is the only upper-middle income country that was in the top ten countries. Other developing countries that contributed articles in the field of OE include Malaysia and Brazil. This, again, raises the issue of non-visibility or lack of publications on OE (or specifically in eco-innovation studies) from the developing countries, most especially in popular databases such as Scopus. Figure 5a also shows the distribution of various countries by the number of articles published represented by the size of the nodes. The bigger the nodes, the bigger the contribution to the OE scholarly literature. Although China is one of the top ten contributors to OE literature (as shown by the size of the node in figure 5a), publications from the country did not make much of an impact on the global scene as represented by the average number of citations depicted in Figure 5b. For instance, while countries such as Italy, Australia, Switzerland and South Korea gathered about 30 citations per article, China only recorded less than 10 citations on the average (see Figure 5b). It should be noted that the links between these countries represent the number of co-authored papers between the countries that are connected with one another. As such, the thicker the link, the more articles authors from the two countries collaborated on (Vatananan-Thesenvitz *et al.*, 2019). Countries with yellow nodes and links such as China, Thailand, Hong Kong and Malaysia represent countries with recent publications on OE (see Figure 5a).

4.2.2 Main sources of external knowledge

This paper also, examined where firms derived their external sources of knowledge for eco-innovation. The results of the analyses reveal that firms derived knowledge from several key stakeholders across the three main sources of knowledge (i.e. analytic, synthetic or symbolic). Some of the key sources include: patents, consultants, private R&D institutes, universities, public research institutes, conferences, trade fairs, exhibitions, scientific journals, trade/technical publications, suppliers, customers, competitors, industrial and eco-designers, professional and industry associations.

Table 3: Geographic Distribution of OE Literature

Country	TP	TC	CPP
Italy	17	728	42.82
Spain	17	436	53.64
United kingdom	15	215	14.33
China	10	45	4.50
United States	10	125	12.50
Germany	8	131	16.38
France	8	94	11.75
Brazil	7	80	11.44
Sweden	6	51	8.50
Denmark	6	30	5.0

**Figure 5a:** Bibliographical coupling by article**Figure 5b:** Bibliographical coupling by citation

However, deeper analyses of these sources show that 39% of the articles reviewed reported that firms consulted universities among other key external knowledge providers. At the same time, 55% of the firms used both analytic and synthetic sources of external knowledge for eco-innovation. Only 5% of the articles reported that firms collaborated across all the three sources of external knowledge providers. This analysis indicates that majority of firms use both analytic and synthetic modes of external knowledge sourcing suggesting that the two modes are complimentary. Meanwhile, very few firms used all the three modes at the same time.

4.3. Emerging research themes from OE research domain

4.3.1. Intellectual structure of the OE knowledge base

This section attempts to unravel common philosophical concepts underlying OE research field. The visualization network map for the authors co-citations is shown in Figure 6. On the network map, the authors are symbolized by nodes. The size of the nodes denotes author's impact. Authors with high impacts are represented with big nodes. For instance, authors with big nodes such as de Marchi, Marzucchi, Mazzanti, Cainelli, Montessor, Ghisetti and Rennings recorded very high co-citations from other authors.

At the same time, the links between authors on the network map stand for the co-citations among them. The thicker the link, the higher the number of co-citations. For example, Figure 6 reveals that there are strong co-citations among de Marchi and authors such as Marzucchi, Mazzanti, del Rio and Montessor. This analysis also groups authors into clusters of common theoretical perspectives or philosophical underpinnings (Vatananan-Thesenvitz *et al.*, 2019). Analysis in Figure 6 shows that there are three groups of authors indicating three different theoretical perspectives.

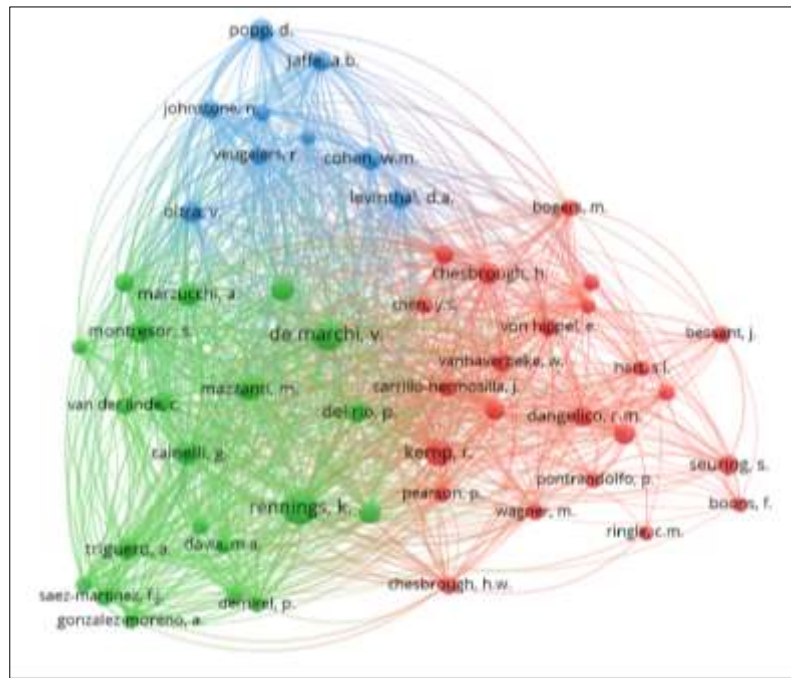


Figure 6: Author co-citation analysis of the OE literature

These perspectives either intersect with the body of literature on OE or serve as background upon which OE developed. For instance, the analysis put authors such as Popp, Jaffe, Johnstone, Oltra, Levinthal, Cohen into the same cluster (blue nodes). Majority of these authors research in the area of economics of innovation, public policy, management science, technological change etc. Very few of them such as Vanessa Oltra, Maïder Saint-Jean and Nick Johnstone actually worked extensively on eco-innovation. None of them could be said to have researched broadly on either open innovation or open eco-innovation. It is also interesting to note that most of the authors that wrote on environmental sustainability in this cluster did their studies when concepts of sustainable development and sustainability were beginning to get into the consciousness of the researchers.

There are other authors clustered together as red nodes. Some of these authors include: Rene Kemp, Eric Von Hippel, Chesbrough Henry, Carrillo-Hermosilla, J. Javier, Teece David John, Rosa Maria Dangelico, Pujari Devashish, Marcus wagner, Pearson P., and Bogers M.. Majority of the authors in this cluster are found to have worked and published articles in the area of open innovation, management science and environmental innovation. However, none of them seem to have worked extensively on open eco-innovation. Another distinct cluster depicted with green nodes reveals authors such as De Marchi, Marzucchi, Mazzanti, Cainelli, Montessor, Ghisetti, del Rio, Rennings, Triguero, Gonzales-Moreno, Demirel P. and Saez-Martinez. We noticed that majority of the authors are researchers in the area of environmental innovation, environmental regulation, eco-innovation policies and open eco-innovation.

Further analyses of these three clusters showed that those authors in the blue nodes could be said to have made contributions to the conceptual and theoretical bases of environmental innovation or eco-innovation. Meanwhile, the authors in the cluster denoted with red nodes could be regarded as those who had shaped the discourse around economics of innovation, environment innovation and open innovation. It will appear then that those authors in the two clusters (those with blue and red nodes) are critical to shaping the trajectories of literature on open eco-innovation. For instance, authors such as Cohen and Levinthal have ground breaking articles on absorptive capacity upon which external knowledge sourcing revolves (Cohen & Levinthal, 1990). At the same time, researchers such as von Hippel and Chesbrough are critical to scholarly contributions on lead user and open innovations (Chesbrough, 2006; Chesbrough, 2003; Von Hippel, 2006, 2007). So it is not surprising then to note that some of the most cited articles on open eco-innovation by De Marchi (2012) and Ghisetti *et al.* (2015) actually referenced all these ground breaking

articles. This goes to show that these clusters could represent theoretical perspectives with which common theory of open eco-innovation could be built.

In terms of the theoretical framework for analysis, articles published in the domain of OE made use of theories and conceptual frameworks such as organizational learning theory, evolutionary theory of technological change, innovation theory, knowledge management theory, dynamic capability theory, institutional theory, stakeholders' theory, absorptive capacity theory, concept of national innovation system, resource-based view, knowledge-based view, and concept of green capabilities among others. The results show that the predominant theoretical frameworks used by the authors include stakeholder's theory, resource-based view, organisational learning theory, knowledge-based view and absorptive capacity theory. We are of the opinion that these theories and frameworks will have significant implications for the development of open eco-innovation theory.

4.3.2. Current trend in OE research landscape

The section discusses the relationship among certain common themes and concepts within OE landscape by using the technique of keyword co-occurrence analysis (Zupic & Čater, 2015). It also shows the niche research clusters that are currently emerging in the OE research field. The most co-occurring keywords are: sustainability, green innovation, eco-innovation, environmental innovation, sustainable development and absorptive capacity (see Figure 7).

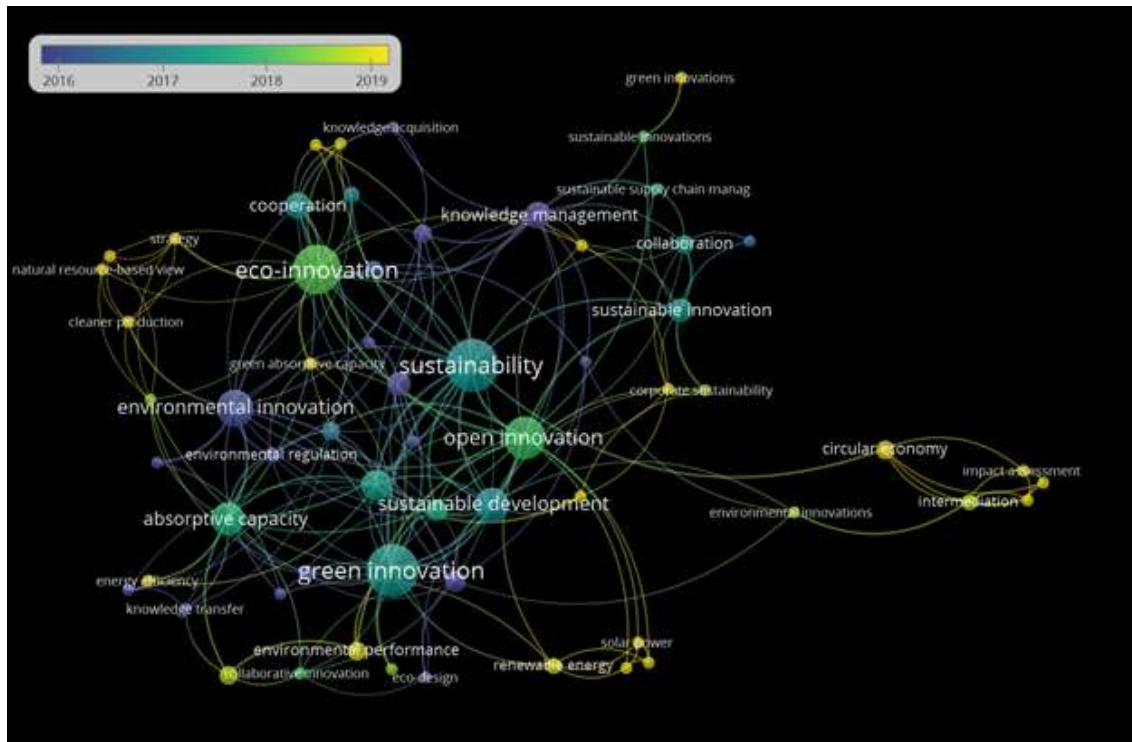


Figure 7: Network Author's keyword co-occurrence map for Open eco-innovation

It is interesting to note that absorptive capacity which is one of the key concepts of open innovation came up as one of the most highly used keywords among the authors. This could be an indication that the concept of OE is beginning to gain ground as an important research field. Due to the closeness of some related nodes (such as environmental innovation, environmental policy, sustainability-oriented innovation and sustainability performance) to more prevalent and bigger nodes (such as sustainability and green innovation), it is possible that these other related, smaller nodes (e.g. environmental innovation, environmental policy) may have originated from the bigger nodes (e.g. Sustainability).

In all, the co-occurrence of the author's keywords generated 9 clusters on the network visualization map representing what could be regarded as research areas/themes. The identifiable research areas/themes around OE include sustainability; collaboration and sustainable innovation; absorptive capacity and environmental performance; green innovation and stakeholder's engagement; eco-innovation and green absorptive capacity; circular economy and sustainability transition; environmental innovation and R&D co-operation; knowledge sourcing strategies and renewable energy; and sustainable innovation. It could be seen on the visualization map that open innovation is located close to both sustainability and sustainable development implying some high level of association with the concept of OE. Yellow nodes on the network map signifies emerging concepts that have just been introduced to the field of OE. For instance, some of the new concepts that showed up on the visualization network map include: circular economy, green absorptive capacity, intermediation, etc. Assessment of these yellow clusters could be an indication of the future trend of OE research landscape. These new research themes have significant implications for researchers, private sector and policy makers. For researchers, these could be emerging areas of interest for further research. For an entrepreneur who is interested in incorporating environmental sustainability into the innovation process, green absorptive capacity and paying attention to the roles of intermediaries in collaborative eco-innovation process is highly relevant. Meanwhile, policy makers should harness the opportunities in eco-innovation efforts in the industrial sector through appropriate economic incentives and regulations.

5. Conclusion, Limitations and Future Research

The open eco-innovation research landscape has experienced considerable growth most especially between 2012 and 2019. At the end of the synthesis of the relevant articles, the study selected a total of 102 journal articles. Bibliometric analysis of publication growth trajectories was conceptualized into four phases: start, acceleration, transition and deceleration. In-depth review of literature shows that the current study is the first to carry out a systematic review of OE research landscape using standard systematic review protocol and bibliometric techniques. The total number of articles in the research domain of OE is increasing at a very fast rate. Based on the conceptualized categorization of publication growth trajectory, it was noted that OE research landscape is at the acceleration phase. The reasons for this could be that this particular research field is emerging and has found relevance in the sustainable innovation landscape. All the selected journals had gathered close to 2500 citations during the analysis of the result. Majority of the literature on OE was published in high impact journals such as RP, EE, BSE and JCP. Under-representation of experts from the developing countries was also revealed as the most productive countries in the field of OE are from Europe and the USA. China, Brazil and Malaysia are the only emerging economies with some sort of significant presence on the OE literature map. Certain current and emerging themes around OE research landscape were detected such as circular economy, green absorptive capacity, intermediation and so on. These new research themes have significant implications for researchers, private sector and policy makers. We noted that the philosophical and theoretical backgrounds surrounding the concept of eco-innovation is presently taking shape around stakeholder's theory, resource-based view, organisational learning theory, knowledge-based view and absorptive capacity theory.

In spite of the robust analysis in this article, there are some limitations, which are also very common to systematic analyses. First, the study used only relevant articles domiciled in Scopus and ResearchGate. Even though Scopus is the largest database of peer-reviewed articles, there are still other databases that may contain articles not listed in Scopus database. However, co-citation analysis would have reduced the effects of this limitation. Also, Scopus is biased towards articles written in English and countries with large number of journals indexed in its database. The second limitation of the study has to do with the fact that the results of the study are based on the current situation of the OE research domain and this could change as new articles emerge and more citations are added to the extant articles. This is why it is important to interpret these results within the context of the study period.

Regardless of the study limitations above, this study has identified some research gaps in the OE research domain. The articles established that majority of the peer-reviewed articles came from the developed

countries while very few scholars from the developing countries have articles indexed in a major popular database such as Scopus, etc. As a result of this, more studies are needed from the developing countries to understand issues surrounding sustainability and open eco-innovation. Another research gap that was observed is that of carrying out a detailed analysis of theoretical perspective underlying the 4 clusters generated by the author co-citation analysis. Understanding these philosophical underpinnings could help shape the introduction of an appropriate theory for OE research domain.

6. Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 846706.

References

- Asheim, B. T., & Gertler, M. S. (2005). The geography of innovation: regional innovation systems. In *The Oxford handbook of innovation*.
- Asheim, Bjorn, Coenen, L., Moodysson, J., & Vang, J. (2007). Constructing knowledge-based regional advantage: implications for regional innovation policy. *International Journal of Entrepreneurship and Innovation Management*, 7(2–5), 140–155.
- Asheim, Bjørn, & Hansen, H. K. (2009). Knowledge bases, talents, and contexts: On the usefulness of the creative class approach in Sweden. *Economic Geography*, 85(4), 425–442.
- Avellaneda-Rivera, L. M., Sáez-Martínez, F. J., & González-Moreno, Á. (2019). Open and eco-innovations in traditional industries. In *Innovation Strategies in Environmental Science* (pp. 145–178). Elsevier.
- Boschma, R. A. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, 39(1), 61–74. <https://doi.org/10.1080/0034340052000320887>
- Brundtland, G. H. (1987). What is sustainable development. *Our Common Future*, 8(9).
- Cainelli, G., De Marchi, V., & Grandinetti, R. (2015). Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms. *Journal of Cleaner Production*, 94, 211–220. <https://doi.org/https://doi.org/10.1016/j.jclepro.2015.02.008>
- Chesbrough, H. (2006). *Open business models: How to thrive in the new innovation landscape*. Harvard Business Press.
- Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press.
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*. <https://doi.org/10.2307/2393553>
- Cristina Díaz-García, M., Moreno, Á. G., Jose Saez-Martinez, F., Díaz-García, C., González-Moreno, Á., Sáez-Martínez, F. J., & C Diaz-Garcia, A Gonzalez-Moreno, F. S.-M. (2015). Eco-innovation: insights from a literature review. *Organization & Management*, 17(1), 6–23. <https://doi.org/10.1080/14479338.2015.1011060>
- Cruz-González, J., López-Sáez, P., Navas-López, J. E., & Delgado-Verde, M. (2015). Open search strategies and firm performance: The different moderating role of technological environmental dynamism. *Technovation*, 35, 32–45. <https://doi.org/10.1016/j.technovation.2014.09.001>
- Dangelico, R. M., Pontrandolfo, P., & Pujari, D. (2013). Developing sustainable new products in the textile and upholstered furniture industries: Role of external integrative capabilities. *Journal of Product Innovation Management*. <https://doi.org/10.1111/jpim.12013>
- De Marchi, V. (2012). Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms. *Research Policy*, 41(3), 614–623. <https://doi.org/https://doi.org/10.1016/j.respol.2011.10.002>
- De Marchi, V., & Grandinetti, R. (2013). Knowledge strategies for environmental innovations: The case of Italian manufacturing firms. *Journal of Knowledge Management*, 17(4), 569–582. <https://doi.org/10.1108/JKM-03-2013-0121>
- Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus,

- web of science, and Google scholar: strengths and weaknesses. *The FASEB Journal*, 22(2), 338–342.
- Fussler, C., & James, P. (1996). *Driving eco-innovation: a breakthrough discipline for innovation and sustainability* Pitman Publishing. London.
- Ghisetti, C., Marzucchi, A., & Montresor, S. (2015). The open eco-innovation mode. An empirical investigation of eleven European countries. *Research Policy*, 44(5), 1080–1093. <https://doi.org/10.1016/j.respol.2014.12.001>
- Ghisetti, C., Montresor, S., & Vezzani, A. (2021). Design and environmental technologies: Does ‘green-matching’ actually help? *Research Policy*, 50(5), 104208. <https://doi.org/10.1016/j.respol.2021.104208>
- Gimenez, C., & Tachizawa, E. M. (2012). Extending sustainability to suppliers: A systematic literature review. In *Supply Chain Management* (Vol. 17, Issue 5, pp. 531–543). <https://doi.org/10.1108/13598541211258591>
- González-Moreno, Á., Triguero, Á., & Sáez-Martínez, F. J. (2019). Many or trusted partners for eco-innovation? The influence of breadth and depth of firms’ knowledge network in the food sector. *Technological Forecasting and Social Change*, 147, 51–62. <https://doi.org/10.1016/j.techfore.2019.06.011>
- Halilem, N. (2010). Inside the Triple Helix: An Integrative Conceptual Framework of the Academic Researcher’s Activities, a Systematic Review. *Journal of Research Administration*, 41(3), 23–50.
- Hazarika, N., & Zhang, X. (2019). Factors that drive and sustain eco-innovation in the construction industry: The case of Hong Kong. *Journal of Cleaner Production*, 238. <https://doi.org/10.1016/j.jclepro.2019.117816>
- Horbach, J., Oltra, V., & Belin, J. (2013). Determinants and Specificities of Eco-Innovations Compared to Other Innovations-An Econometric Analysis for the French and German Industry Based on the Community Innovation Survey. *Industry and Innovation*, 20(6), 523–543. <https://doi.org/10.1080/13662716.2013.833375>
- James, P. (1997). The sustainability cycle: a new tool for product development and design. *The Journal of Sustainable Product Design*, 52–57.
- Jeong, H. J., & Ko, Y. (2016). Configuring an alliance portfolio for eco-friendly innovation in the car industry: Hyundai and Toyota. *Journal of Open Innovation: Technology, Market, and Complexity*, 2(1), 1–16.
- Katila, R., & Ahuja, G. (2002). Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal*, 45(6), 1183–1194.
- Kim, C., Lee, C., & Kang, J. (2018). Determinants of firm’s innovation-related external knowledge search strategy: The role of potential absorptive capacity and appropriability regime. *International Journal of Innovation Management*, 22(6). <https://doi.org/10.1142/S1363919618500445>
- Klewitz, J., Zeyen, A., & Hansen, E. G. (2012). Intermediaries driving eco-innovation in SMEs: A qualitative investigation. *European Journal of Innovation Management*, 15(4), 442–467. <https://doi.org/10.1108/14601061211272376>
- Laestadius, S. (1998). *Technology level, knowledge formation, and industrial competence in paper manufacturing*.
- Laursen, K., & Salter, A. (2006). Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strategic Management Journal*, 27(2), 131–150. <https://doi.org/10.1002/smj.507>
- Martin, R., & Moodysson, J. (2011). Innovation in symbolic industries: The geography and organization of knowledge sourcing. *European Planning Studies*, 19(7), 1183–1203.
- Marzucchi, A., & Montresor, S. (2016). *Forms of knowledge and ecoinnovation modes: Evidence from Spanish manufacturing firms* *Forms of knowledge and eco-innovation modes: Evidence from Spanish manufacturing firms*. <https://doi.org/10.1016/j.ecolecon.2016.08.032>
- Marzucchi, A., & Montresor, S. (2017). Forms of knowledge and eco-innovation modes: Evidence from Spanish manufacturing firms. *Ecological Economics*, 131, 208–221. <https://doi.org/10.1016/j.ecolecon.2016.08.032>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & others. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg*, 8(5), 336–341.

- Nerur, S. P., Rasheed, A. A., & Natarajan, V. (2008). The intellectual structure of the strategic management field: An author co-citation analysis. *Strategic Management Journal*, 29(3), 319–336.
- Oltra, V., & Saint Jean, M. (2009). Sectoral systems of environmental innovation: An application to the French automotive industry. *Technological Forecasting and Social Change*, 76(4), 567–583. <https://doi.org/10.1016/j.techfore.2008.03.025>
- Ornetzeder, M., & Rohracher, H. (2006). User-led innovations and participation processes: lessons from sustainable energy technologies. *Energy Policy*, 34(2), 138–150. <https://doi.org/https://doi.org/10.1016/j.enpol.2004.08.037>
- Pacheco, D. A. de J., Caten, C. S. ten, Jung, C. F., Navas, H. V. G., & Cruz-Machado, V. A. (2018). Eco-innovation determinants in manufacturing SMEs from emerging markets: Systematic literature review and challenges. *Journal of Engineering and Technology Management - JET-M*, 48, 44–63. <https://doi.org/10.1016/j.jengtecman.2018.04.002>
- Pham, D. D. T., Paillé, P., & Halilem, N. (2019). Systematic review on environmental innovativeness: A knowledge-based resource view. In *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2018.11.221>
- Rennings, K. (2000). Redefining innovation - Eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2), 319–332. [https://doi.org/10.1016/S0921-8009\(99\)00112-3](https://doi.org/10.1016/S0921-8009(99)00112-3)
- Rennings, K., & Rammer, C. (2009). *Increasing energy and resource efficiency through innovation: an explorative analysis using innovation survey data*.
- Sáez-Martínez, F. J., Díaz-García, C., & Gonzalez-Moreno, A. (2016). Firm technological trajectory as a driver of eco-innovation in young small and medium-sized enterprises. *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2016.04.108>
- Schubert, A., & Láng, I. (2005). The literature aftermath of the Brundtland report ‘Our common future’. A scientometric study based on citations in science and social science journals. *Environment, Development and Sustainability*, 7(1), 1–8.
- Snilstveit, B., Oliver, S., & Vojtkova, M. (2012). Narrative approaches to systematic review and synthesis of evidence for international development policy and practice. *Journal of Development Effectiveness*, 4(3), 409–429.
- Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509–533. [https://doi.org/10.1002/\(SICI\)1097-0266\(199708\)18:7<509::AID-SMJ882>3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z)
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), 207–222.
- Van Eck, N. J., & Waltman, L. (2013). VOSviewer manual. *Leiden: Univeriteit Leiden*, 1(1), 1–53.
- Vatananan-Thesenvitz, R., Schaller, A.-A., & Shannon, R. (2019). A Bibliometric Review of the Knowledge Base for Innovation in Sustainable Development. *Sustainability*, 11(20), 5783. <https://doi.org/10.3390/su11205783>
- Veronica, S., Alexeis, G.-P. P., Valentina, C., & Elisa, G. (2019). Do stakeholder capabilities promote sustainable business innovation in small and medium-sized enterprises? Evidence from Italy. *Journal of Business Research*. <https://doi.org/https://doi.org/10.1016/j.jbusres.2019.06.025>
- Vickers, I., & Cordey-Hayes, M. (1999). Cleaner production and organizational learning. *Technology Analysis and Strategic Management*, 11(1), 75–94. <https://doi.org/10.1080/095373299107591>
- Von Hippel, E. (2006). *Democratizing innovation*. the MIT Press.
- Von Hippel, E. (2007). The sources of innovation. In *Das Summa Summarum des Management* (pp. 111–120). Springer.
- Xavier, A. F., Naveiro, R. M., Aoussat, A., & Reyes, T. (2017). Systematic literature review of eco-innovation models: Opportunities and recommendations for future research. In *Journal of Cleaner Production* (Vol. 149, pp. 1278–1302). Elsevier Ltd. <https://doi.org/10.1016/j.jclepro.2017.02.145>
- Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, 18(3), 429–472.