Open Eco-Innovation Research Landscape: A Systematic Review and Future Outlook

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Abstract

The paper carries out a systematic review of the literature on the emerging themes in open eco-innovation (OE), and most specifically on the role of internal and external knowledge sourcing for firms. Open innovation runs contrary to the individualistic mentality of traditional corporate R&D implementation while embracing external cooperation in a complex world. Our main motivation for the study is to assess and characterise literature that represents radical transformation toward accelerating co-development of sustainable innovations. Our review points to the role of the open eco-innovation research landscape as an emerging research domain of potential contributions to sustainable industrial development. Specifically, in this systematic analysis, we apply exploratory, bibliometric, and network visualization techniques to characterize the available knowledge in the field. We trace the growth trajectory of this emerging literature and map the knowledge base of the OE research field. Based on the data from our study we developed four phases of knowledge domain development and recognised that OE is at the acceleration phase. We emphasized that analytic knowledge base is one of the basic ingredients of an open eco-innovation model in addition to synthetic and symbolic knowledge bases. Our article also brought to the fore the emerging important role of intermediaries in brokering eco-innovation at the firm and sectoral levels with a lot of implications for policymaking. Finally, we highlighted what might seem to be budding theoretical perspectives underlining open eco-innovation in the industrial sector.

Keywords: Open eco-innovation; external knowledge sourcing; bibliometric technique; systematic literature review; open innovation; co-citation analysis;
JEL Classification: O36; Q55; Q56

1. Introduction

Innovation is an effective strategy for combating CO_2 emissions as it promotes cost-effective solutions such as energy efficiency and cleaner technologies. However, it has not been given due consideration in many developing countries because of inadequate technological capabilities and lack of effective collaboration between the south and the north on sustainability pathways (Adenle et al., 2015). Meanwhile, the developing countries, cannot accelerate the transition to low-carbon innovation development by absolutely depending only on the internal resources. Efforts to combat environmental challenges require cross-fertilization of ideas and cooperation with external partners. Open eco-innovation has the potentials to engender international collaborations among countries and multinational enterprises that permit knowledge spillovers which promote the diffusion of clean technological innovations (Dauda et al., 2021; Sarkodie & Strezov, 2019).

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 (Chesbrough, 2003; Cruz-González et al., 2015; Grimpe & Sofka, 2009). 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). According to traditional economics theory, there is a disincentive to invest in eco-innovation because the value created by an eco-innovative firm often accrues to other firms due to knowledge spillover. This externality and many others create market failures which have induced the need for regulatory policy 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 the mainstream innovation (de Marchi & Grandinetti, 2013). In fact, eco-innovation is known to require more external knowledge than conventional innovation (Horbach et al., 2013). Based on these facts, it is clear that external source of knowledge is an important driver of eco-innovation, and one that should be considered in environmental innovation studies (Jeong & Ko, 2016).

To the best of our knowledge, no other study has 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 literature review (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 is any potential opportunity for theory development.

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 emerging research themes from 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.

2.1. Eco-innovation and External Knowledge Sourcing

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 the new process 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 attempts 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; Martin & Moodysson, 2011)

3. Methods

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;

(4) evaluating the quality of the selected studies;
(5) data extraction, coding and monitoring progress; and
(6) 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) where we attempt to make sense out of the findings in the selected articles. We also use bibliometric and network visualization mapping techniques 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, p53) 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 will be considering 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 will be to choose only online peer-reviewed articles published within the period specified above. This criterion will allow us evaluate papers that have undergone thorough review process by the researchers and experts in the field of environmental sustainability. We excluded 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.

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.

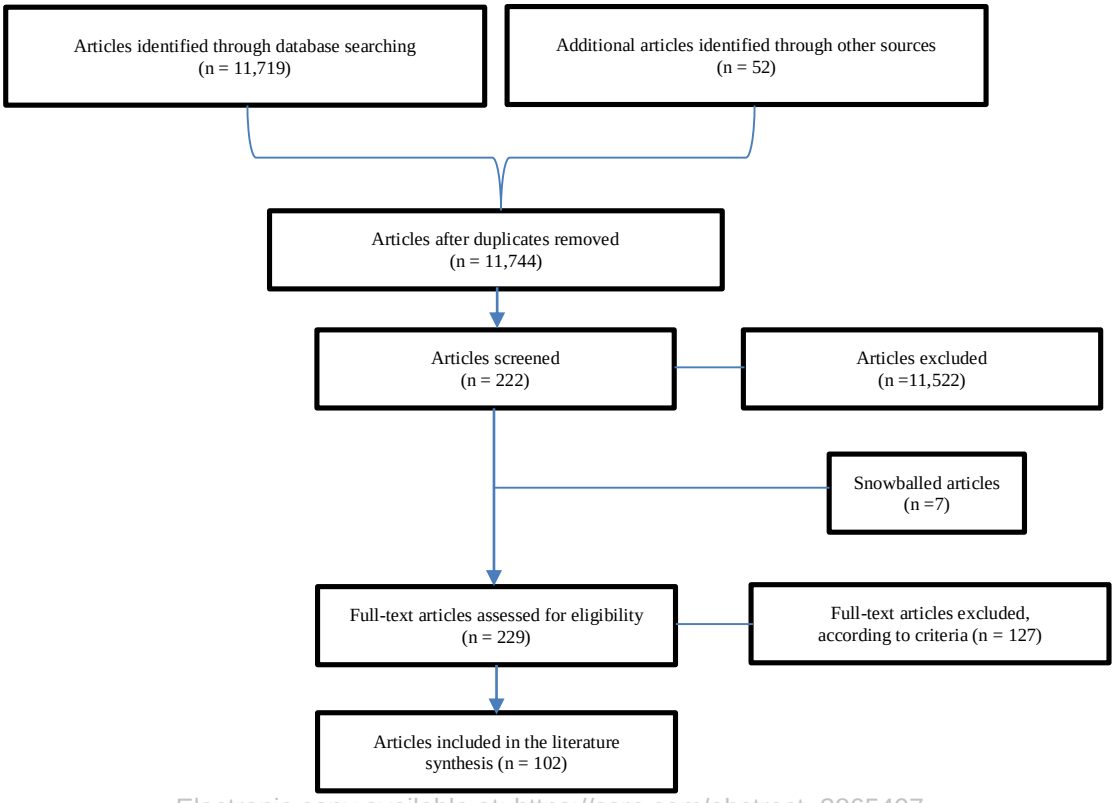
In order to locate and select articles that fulfil our criteria, we performed a search mainly across Scopus database. In this review, we based our analysis on this database because it offers a great flexibility, particularly with regard to search terms and citations search. It is also one of the largest abstract and citation databases of peer-reviewed literature. Our

paper established keywords and search strings that allows the combination of keywords and their synonyms into logical expressions to incorporate many journals in the field of interest (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 our paper will consider these four terms as interchangeable and identical (Xavier et al., 2017). Additional search was conducted manually on ResearchGate database. This database afforded us the flexibility of contacting authors that are registered in the database directly to share their articles with us. The first search on Scopus yielded a total of 16,315 journal articles. It was later reduced to 11, 719 when we narrow down the disciplines of interest to “Social Sciences”, “Business, Management and Accounting” and “Decision Sciences” ‘‘environmental science’’, ‘‘energy’’, ‘‘economics’’, ‘‘econometrics’’ and ‘‘finance’’. In addition to these journals, we also retrieved an additional 52 peer reviewed articles through our search on ResearchGate.

Selecting articles

In order to select the relevant literature for the study, we adapted Chesbrough & Bogers' (2014) definition of open innovation. We describe open eco-innovation as a decentralized eco-innovation process based on controlled knowledge flows across organizational boundaries, using pecuniary and non-pecuniary strategies in accordance with the organization's business model. Therefore, we selected any peer-reviewed articles that examine firms sourcing knowledge resources or collaborating with external actors such as customers, suppliers, universities, research institutes, consultants, professional associations, formal and informal social networks etc. to eco-innovate. Selecting the last set of articles for review consists of two steps. 222 articles were selected in the first round. After the second step, we came up with the final sample of 102 selected journal articles. 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 comprehensive insight into the knowledge base of OE, we conducted bibliometric analysis. Bibliometric 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). We employed the use of VOSviewer software to visualize the bibliometric dataset from Scopus (Van Eck & Waltman, 2013). With the aid of VOSviewer, we carried out the following analyses which enable us to comprehend the development and trajectory of OE in sustainability study landscape. 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 Discussions

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, we conceptualize and develop four phases of knowledge domain development: 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, pronouncement of sustainable development goals etc. 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, we recognize two phases from the analysis of OE research landscape based on the conceptualized four phases explained above. 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 our sample was published in 1999 (Vickers & Cordey-Hayes, 1999) as we did not find any article in the Scopus database that directly explored open eco-innovation concept between 1990 and 1998. 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 phenomenon 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 & Rohracher, 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

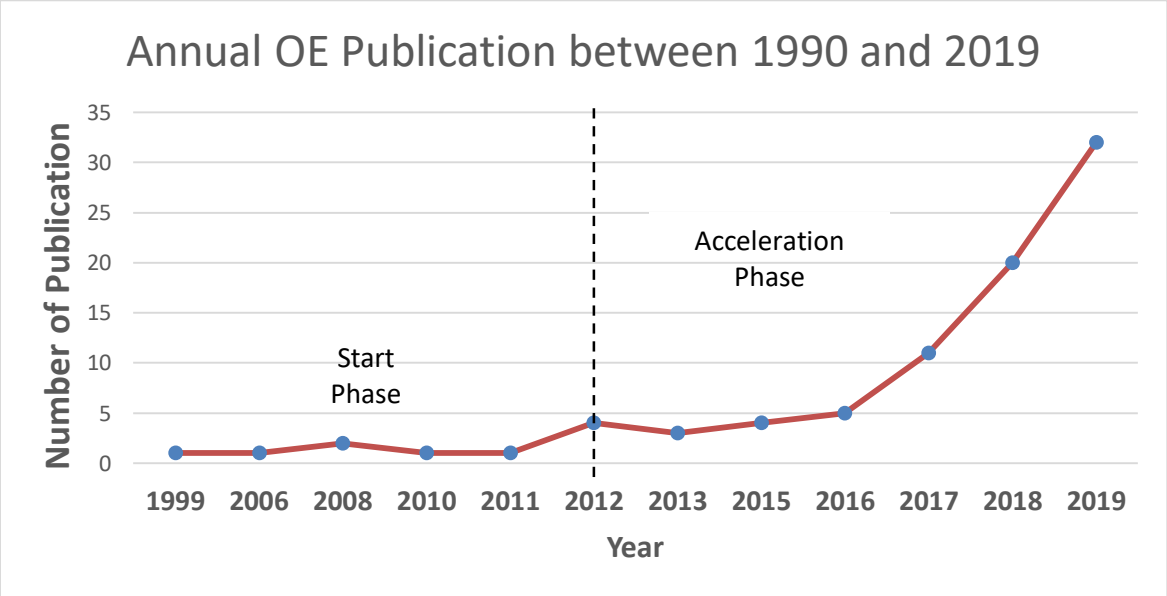
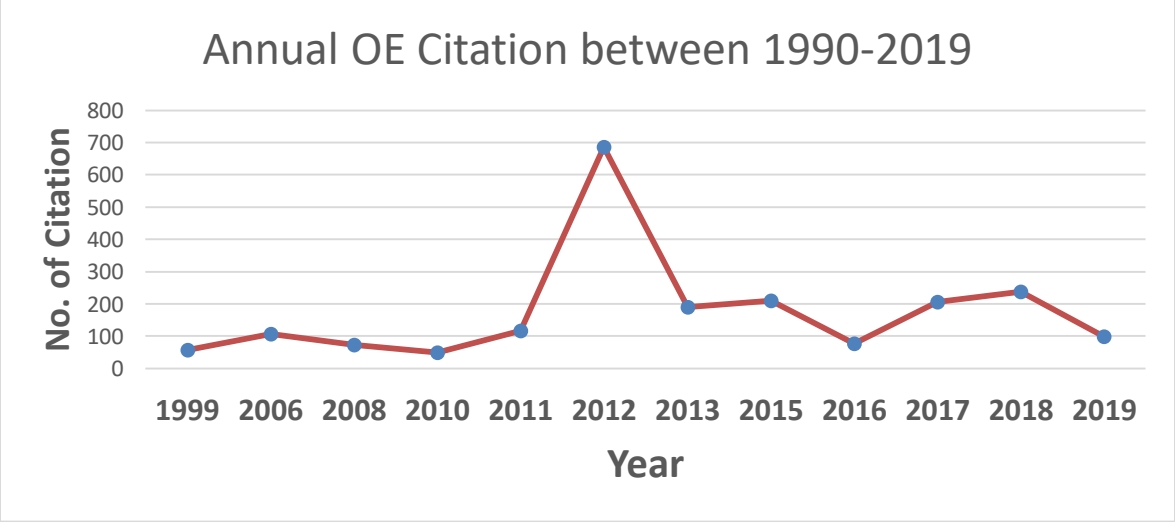


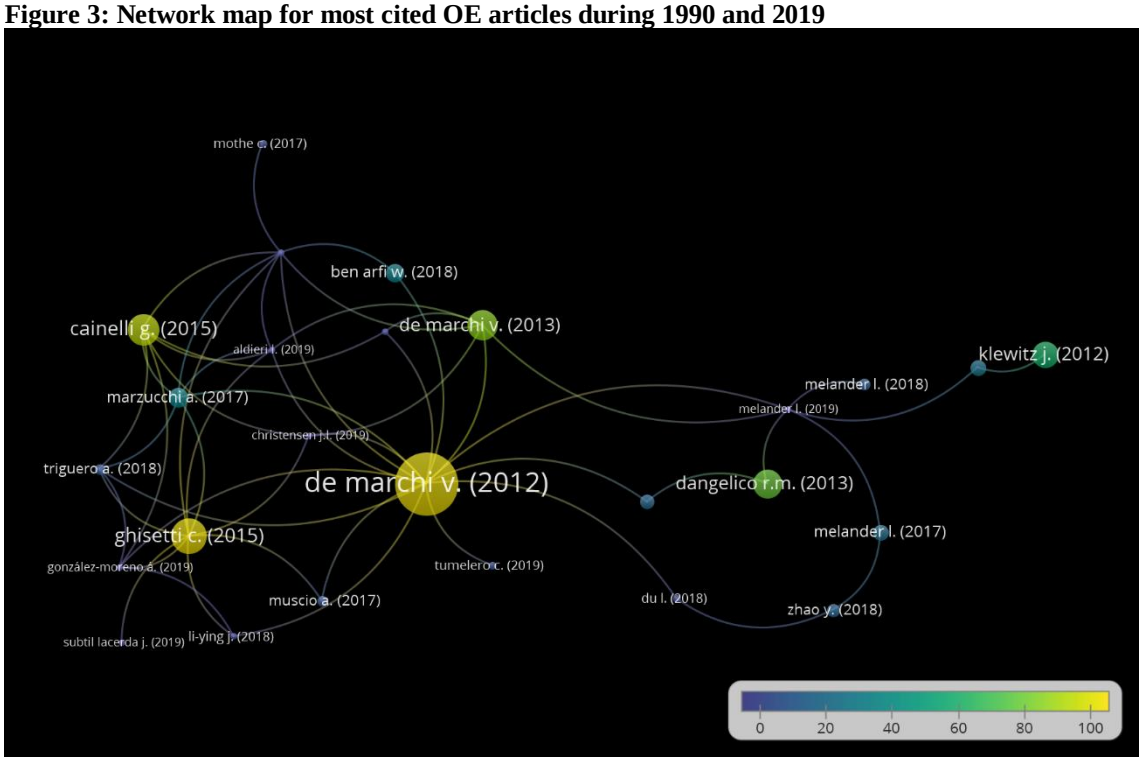
Figure 2b: Annual OE Citation between 1990-2019



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 (Cainelli et 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 & Grandinetti, 2013), (Dangelico et al., 2013), (Klewitz et al., 2012) and(Marzucchi & 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) etc. 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 3 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, the Journal of Cleaner Production (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 Ecological Economics (EE) with 4 publications. Other high impact journals such as Research Policy (RP) and Energy Policy (EP) have 3 articles each. Meanwhile, in terms of impact of the articles in each of the journal, articles in JCP has less impacts when compared with RP, SCM and EE. For instance, Research Policy (RP), Supply Chain Management (SCM) and EE recorded 150, 138.50 and 13.33 citations per publication compared with 13.40 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 type 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 article, 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). Once again, Figure 4b buttresses the point about relative impact of journals like RP, SCM. For instance, RP, SCM and Journal of Knowledge Management (JKM) with red nodes recorded average of around 80 citations per articles compared with articles published in JCP and BSE which recorded less than 20 citations per articles on the average. Analysis of citations per publication (CPP) in table 3 also emphasized this fact. Results in table 3 further shows that OE has attracted interests of scholars from various field including environmental science, science, technology and innovation (STI) management, supply value chain management, ecological economics, energy policy, knowledge management etc.

Table 3: The leading 10 productive journals in OE

Journal	Field of the Journal	TP	TP R (%)	IF	TC	CPP
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

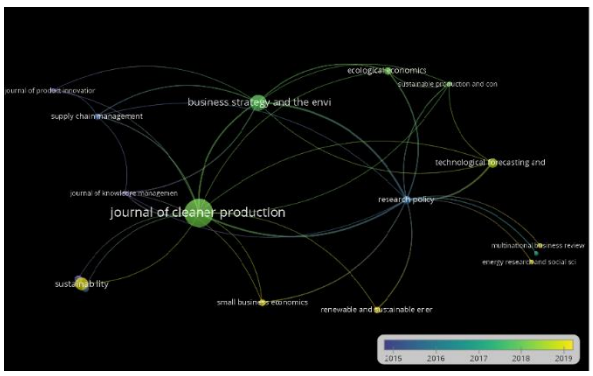
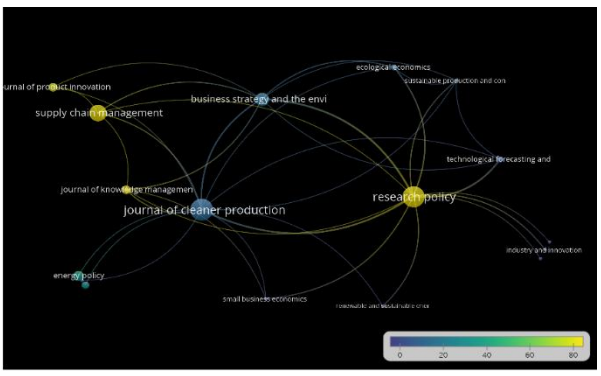


Figure 4b: Bibliographical coupling by citation



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

4.2.1. Geographic Distribution of OE Literature

Table 4 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 region. This is closely followed by the United Kingdom (15). China (10) and the United States (10) are also among the leading countries in the production of OE literature. In all, 10 leading countries accounted for over 90% of the total knowledge production of OE in Scopus database within the study period. It is interesting to note that China is the only upper-middle income country that made the top ten. 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 does 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 around 30 citations per article on the average, 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 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).

Table 4: 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

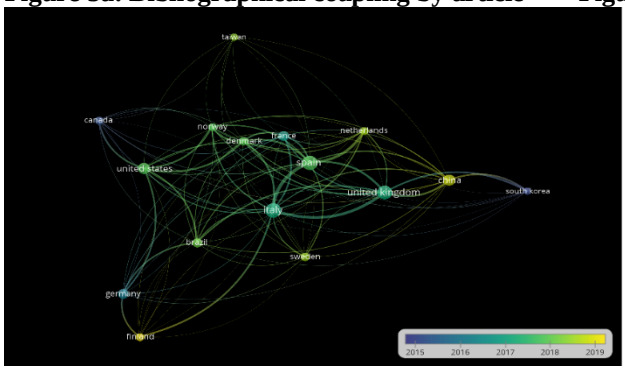
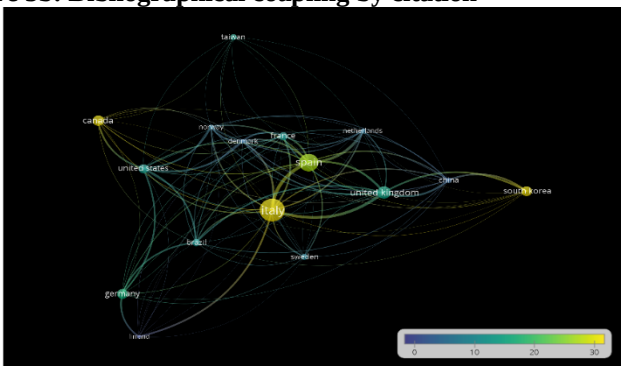


Figure 5b: Bibliographical coupling by citation



4.2.2 Main sources of external knowledge

This paper also examined where firms derived their external sources of knowledge for eco-innovation: analytic, synthetic or symbolic. 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 etc. 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 use 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, Montressor, 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 revealed that there are strong co-citations among de Marchi and authors such as Marzucchi, Mazzanti, del Rio and Montressor.

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. 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 Vannessa 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.

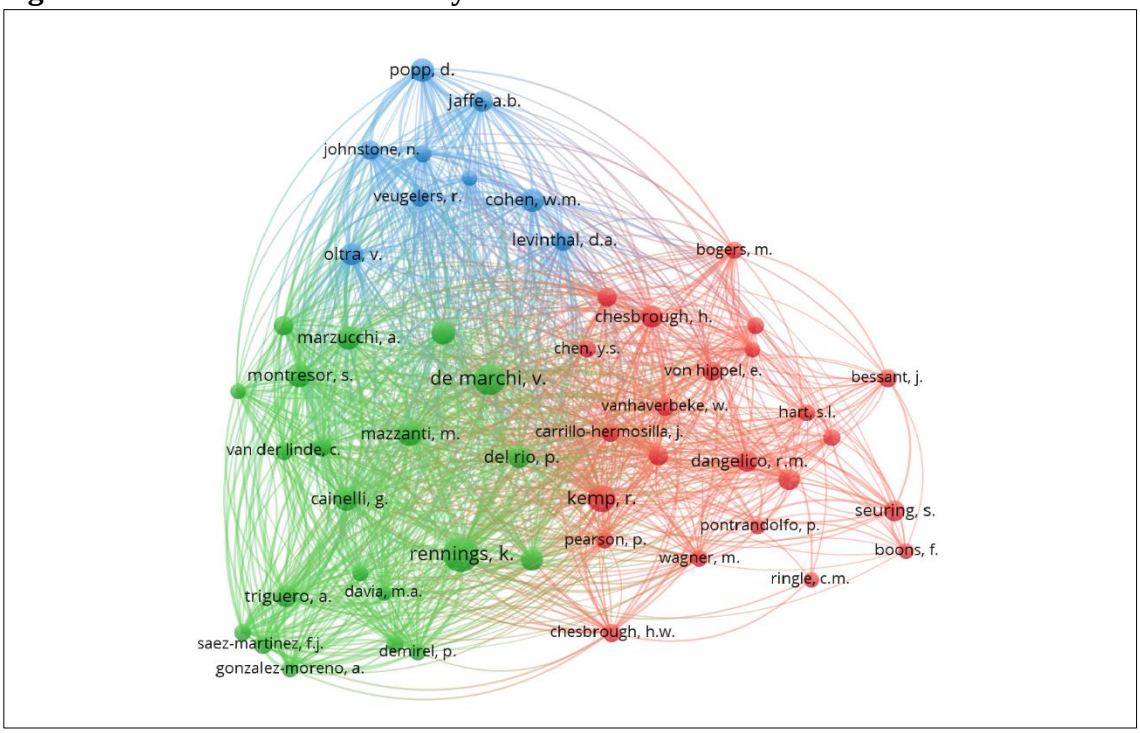
There are other authors clustered together as red nodes. Some of these authors include Rene Kemp, Eric Von Hippel, Chesbrough Henry, Carrillo-Hermosilla, J. Javier, Teece David John, Rosa Maria Dangelico, Pujari Devashish, Marcus wagner, Pearson P., Bogers M. etc. Majority of the authors in this cluster 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, Montressor, 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 anlayses 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 with 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 notice 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 framework 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, concept of green capabilities etc. Our result shows 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.

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



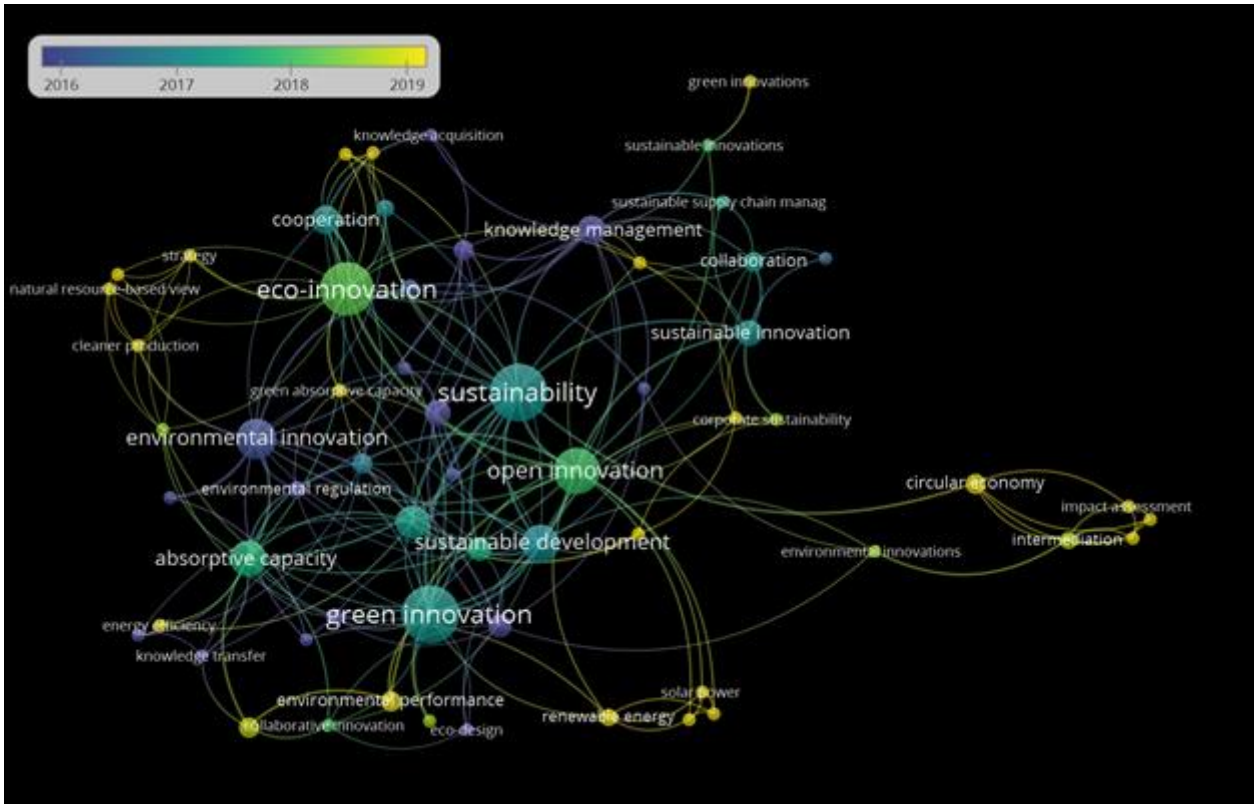
4.3.2. Current trend in OE research landscape

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). 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.

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



5. Conclusion

5.1. Conclusions, 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 We conceptualized bibliometric analysis of publication growth trajectories into four phases: start, acceleration, transition and deceleration. To the best of our knowledge, the current study is the first to carry out 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 our conceptualized categorization of publication growth trajectory, we 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 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 on high impact journals such as RP, EE, BSE and JCP. We also noticed under-representation of experts from the developing countries as the most productive countries on the field of OE are dominated by Europeans and the United States of America. China, Brazil and Malaysia are the only emerging economies with some sort of significant presence on the OE literature map. We detected certain current and emerging themes around OE research landscape such as circular economy, green absorptive capacity, intermediation etc. 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. 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 the results of the study 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 3 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.

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