

Systematic Literature Review and Meta-Analysis

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A Bibliometric Analysis of Green Innovation Research

Huma Sikandar

Azman Hashim International Business School (AHIBS), Universiti Teknologi Malaysia (UTM), 81310, Johor Bahru, Johor, Malaysia

Umar Haiyat Abdul Kohar

Azman Hashim International Business School (AHIBS), Universiti Teknologi Malaysia (UTM), 81310, Johor Bahru, Johor, Malaysia

Corresponding author: huma.sikandar@gmail.com

Abstract

Green innovation has grown in organisational importance as a result of its contribution to meeting environmental needs while also allowing businesses to differentiate themselves from their competitors and hence gain sustainable competitive advantages. Given its importance it feels important to conduct a bibliometric analysis to forecast the growth of green innovation research publications. This paper explores all the disciplines in which green innovation research is published. The Scopus database is used to find published literature in the field, and bibliometric analysis was used to show trends in scholarly and professional publications. This paper examines the status and evolution of 1094 published articles on green innovation research from 1995 to 2021. This study presents the most productive countries, top authors, top journals, and most cited articles as a result of this research. Through co-authorship analysis we identified the countries involved in collaborative research and through co-occurrence of keyword we identified the hot topics in green innovation research and also the emerging topic whose relationship with green innovation is yet to be explored. The limitations and future directions of research has also been provided at the end. This document is intended to serve as a guide for researchers who are new to the field of green innovation and want to improve their knowledge of the subject by identifying the best journals, authors, and papers from which to build their theoretical framework or construct future research models.

Keywords: *Green innovation, bibliometric analysis, sustainability, Scopus database,*

1.1. Introduction

Nowadays, organisations use innovation as a tool to grow their market share and stay in business in the long run. A successful invention improves the market position, attracts potential customers, and gives the company a competitive advantage (Lin et al., 2014). Research in Green innovation area has primarily seen a rising trend in recent years. Green innovation is crucial for organisations and communities to preserve environment. Green innovation has become a popular technique for achieving both environmental conservation and economic prosperity (Karimi Takalo et al., 2021). In recent years, rising environmental concerns around the world, strict regulations for environmental protection, international conventions for sustainability and an increase in the number of environmentally conscious consumers have prompted industries to devote significant resources to developing green practises (Albort-Morant et al., 2017). Environmental sustainability is an important as economic profitability. Green innovation can lead organizations towards attaining sustainable competitive advantages (Karimi Takalo et al., 2021). It assists customers in meeting their demands to protect the environment in which they live (Lin et al., 2014). Green innovation increases resource productivity by ensuring material conservation, lowering energy consumption, promoting waste recycling, and using less resources (Bernauer et al., 2007; Lin et al., 2014).

Green innovation is defined as product and process innovations that attempt to meet environmental goals and reduce a product's environmental footprint over its entire life cycle (Lin et al., 2014). Green innovation refers to pollution-prevention, energy saving, and green design developments on products and in production processes (Albort-Morant et al., 2016). As a

result, greening the innovation process can reduce negative environmental impacts, improve climate change understanding, and assist enterprises in achieving economic, environmental, and social goals, all of which will improve the firm's sustainability and performance (Albort-Morant et al., 2016; Laforet, 2009; Oduro et al., 2021). Green innovation as defined by Organisation for Economic Co-operation and Development (OECD) as "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which with or without intent – lead to environmental improvements compared to relevant alternatives" Green innovation, according to this definition, entails not just "greening" products and processes, but also using green marketing strategies and internal organisational structures and systems to reduce the negative impact of firms on the environment (Oduro et al., 2021).

Despite the fact that the issue of environmental sustainability and innovation has grown in popularity among academics over the last two decades, the concept of defining the types of innovation that minimise negative environmental effects remains elusive and academic terminology is lacking (Oduro et al., 2021). As a result, in the literature, terms like "green," "eco," "environmental," "ecological," and "sustainable" are used interchangeably to describe the same phenomenon. The most prominent notions used in the literature are "green", "eco", "environmental" and "sustainable" to describe the innovation with reduced negative environmental impact. Eco-innovation is defined as "new products and processes that provide customers and businesses value but significantly decrease environmental impact" (Pujari et al., 2003)(Przychodzen and Przychodzen, 2013). Oltra and Saint Jean, (2009, p.567) define environmental innovation "as innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability". Sustainable innovation is a process where financial, environmental and social considerations are integrated into a firm's system from idea generation through to research and development and commercialisation (Charter and Clark, 2007). To summarise, the four definitions of sustainable, eco, environmental, and green innovation discussed above have minor differences in descriptive precision. In terms of content, they appear to be discussing the same subject and can be used interchangeably (Schiederig et al., 2011). All of the definitions cited agree that the innovation should have a lower negative impact on the environment.

Numerous bibliometric analysis and review papers has been published in the past few years but most of them have considered all the four notions of green innovation. Previously (Albort-Morant et al., 2016) performed a bibliometric analysis on the green innovation literature but their dataset was taken from web of Science (WOS) also the timeframe was from 1970 to 2015. Albort-Morant et al., (2016) called for bibliometric analysis of the green innovation literature from other databases besides web of science (WOS). This article is a response to that call. Recently (Oduro et al., 2021) and (Karimi Takalo et al., 2021) also performed content and descriptive analysis through systematic review but the bibliometric content was missing in these studies. To fill this research gap, we used the Scopus database to conduct a bibliometric analysis of green innovation literature in order to gather additional information and gain a deeper understanding of the subject. Also, find out what the most recent research trends are in the field of green innovation. The bibliometric methodology allows the study domain to be given shape, structure, and direction as it evolves and develops. This study presents the general overview of past literature of green innovation and can serve as a point of reference for future researchers who want to become acquainted with the green innovation literature and past trends.

This paper is organised as follows: The first section provides a brief overview and introduction to the green innovation literature in order to demonstrate the importance of the topic and outline its scope. In the second section, the methodology has been explained. The third section demonstrates the findings of the bibliometric analysis. The fourth section presents the conclusion followed by the limitations and possible avenues for future study in the fifth section.

This analysis is not confined to any one language, document type, or country because the goal of this study is to gain an overall perspective of the growth of research on green innovation. This study examines academic articles published between 1995 and 2021. Using a combination of descriptive, bibliometric, and visualization analyses we address the following research questions:

How has green innovation research progressed over time?

What are the most influential journals, authors, and research papers in the field?

What are the most cited articles in green innovation literature?

What are the top productive countries doing collaborative research in green innovation field?

Which are the most addressed research topics in the green innovation research?

1.2. Methodology

1.2.1. Data Collection and Literature Search Strategy

To answer the research questions the authors conducted bibliometric analysis using data from Scopus database. The search was performed on 3rd December 2021. To select a set of papers as start set, the author conducts a primary search with search term “green innovation”. For exploring the growth trends in academic and professional literature on green innovation the 1995-to-2021-time window was selected as the time frame for analysis. The resulting articles received were 1237 on which we performed few filters to get the desired number of articles. Only 6 articles from 2022 were excluded from this study because it didn't seem justified because they were just few in number. A total of 1202 articles selected from journals, conference proceedings, reviews and book chapters were identified. The publication stage was set to final so that we can exclude the articles in press since it is the end of year and we do not wish to include the papers from 2022. The resulting articles were 1122 in number. After selecting the articles published in English language, we obtained 1094 articles (figure 1) that belonged to various disciplines such as Environmental Science, Business, Management and Accounting, Social Sciences, Energy, Engineering, Economics, Econometrics and Finance, Computer Science, Decision Sciences, Earth and Planetary Sciences, Agricultural and Biological Sciences etc.

For this investigation, the Scopus database was used. This database was chosen as a research platform because it is one of the most comprehensive databases for journals, books, and conferences in the world, with a vast coverage of articles (Baas et al., 2020; Sikandar et al., 2021).

1.2.2. Bibliometric tools

Bibliometric analyses are used by field experts to exploit, organise, and analyse material in a certain field in order to assess scientific activities (Albort-Morant et al., 2016). Bibliometric studies are known to help professionals and scholars map knowledge about a topic, enabling them in obtaining information for decision-making and directing future research on the topic. In this study the bibliometric analysis is performed through Vos Viewer software.

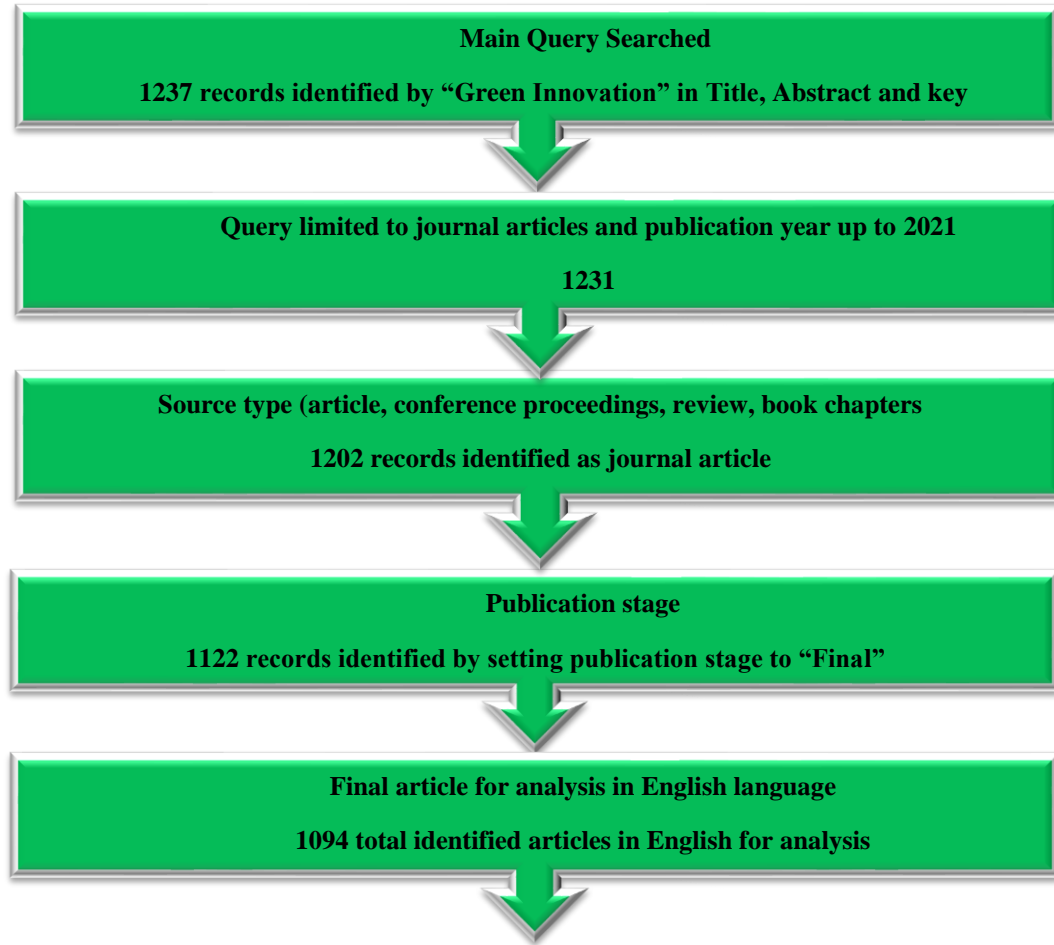


Figure 1: search and selection strategy

1.3.Results

1.3.1. Publication Output

Out of the 1084 documents identified for the analysis, 860 were journal articles, 141 were conference papers, 53 belonged to book chapters and 40 were review articles.

Figure 1 shows how the literature of Green Innovation has evolved over years. It is evident that there has been a significant growth in the publication of articles in the field of green innovation after 2012. The trendline can be divide into 3 segments i.e. 1995-2008 where the number of published articles per year is observed to be less than 10. In the second segment (2009-2015) there has been a moderate growth in the publication and the number of published articles reached to about 40 articles per year. In the third segment a tremendous growth has been observed in the published literature where the number reached from 60 to 290 over the past six years. The highest number of articles were published in 2021 which is 290 articles. The increase in the published articles may be because of the growing interest of academicians and practitioners in the field of green innovation. This pattern is anticipated to increase in 2021 and the subsequent years because of the growing awareness of the consumers and the pressure from the stakeholders and the government on the businesses to perform innovations with reduced environmental impact.

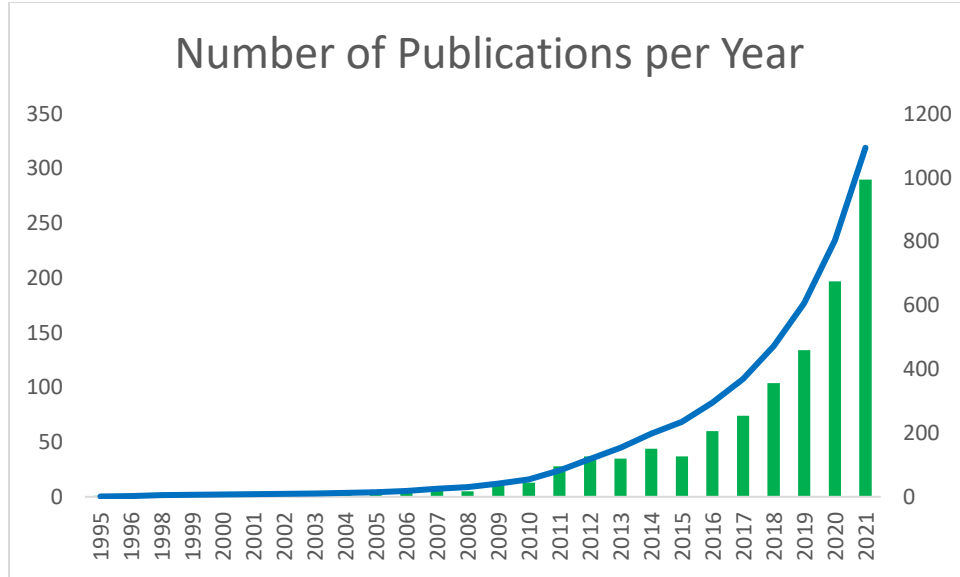


Figure 2: Publication trend

1.3.2. Top productive countries

The top productive countries with most publication in the green innovation field is shown in figure 3. The top three most productive countries are China (444 publications), United States (86 publications) and United Kingdom (75 publications).

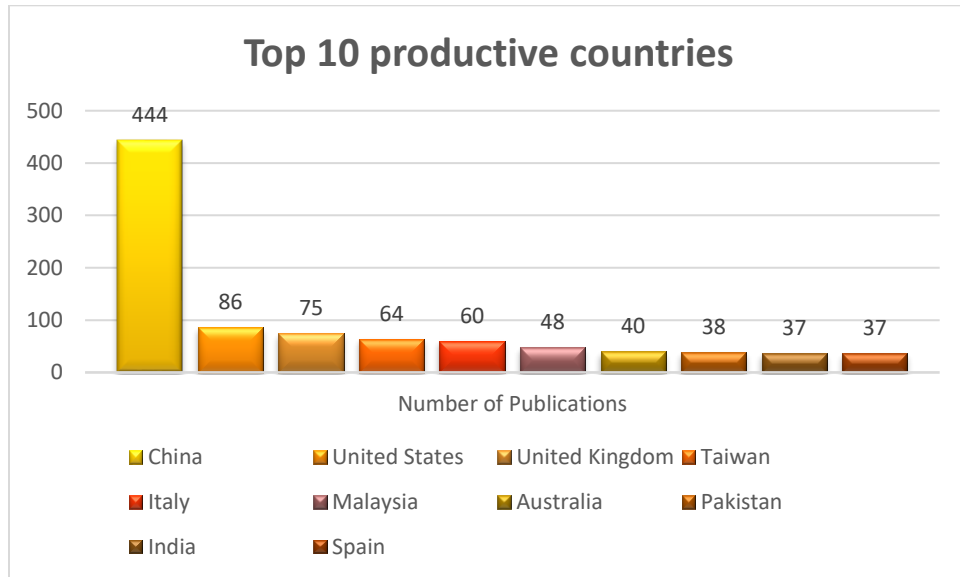


Figure 3: Top Productive countries

One of the more interesting findings of the study is that only one Malaysian institute made the top ten list of institutions. The remaining nine institutions were all owned by China, which means none of the other institutions have as many publications in the field of green innovation as these nine Chinese institutions. It's also a fascinating because it reveals China's interest in green innovation and implementation in comparison to the rest of the world, at least in terms of academics.

Table 1: The top 10 most productive institutions

Rank	Institution	Country	No. of Publications
1	Harbin Engineering University	China	28
2	Northwestern Polytechnical University	China	21
3	Xi'an Jiaotong University	China	16
4	Central South University	China	13
5	Universiti Sains Malaysia	Malaysia	12
6	Tianjin University	China	12
7	Wuhan University of Technology	China	12
8	Harbin University of Science and Technology	China	12
9	Jiangsu University	China	11
10	Xiamen University	China	11

1.3.3. Top 10 Journals

The top 10 journals are listed in table 2. Our findings revealed that Journal of Cleaner Production, Sustainability Switzerland, and Business Strategy And The Environment are the top three journals in the field of green innovation with most publication 98,96 and 49 total publication (TP) each.

However, in terms of citations Journal of Cleaner Production is at the top with 4388 publications, followed by Journal of Business Ethics with 2250 publications and Business Strategy and The Environment with 1835 publications. The most cited paper of this journal is "The influence of green innovation performance on corporate advantage in Taiwan," which has 755 citations and is published in the Journal of Business Ethics.

According to 2020 report CiteScore, 5 of the top 10 journals has CiteScore more than ten. The highest CiteScore is 13.1 for Journal of Cleaner Production, while the lowest is 3.4 for International Journal Of Environmental Research And Public Health. We can understand that CiteScore might impact the author's decisions in selecting journals which are more novel and important. Scopus database uses CiteScore which is considered as the alternative to Impact Factor in the Clarivate Analytics. To save our fellow researchers time to find the best journals related to green innovation, we included the top 10 CiteScore journals in Table 2. The table demonstrates the top 10 journals and their publisher names, total publications, total citations, most cited articles of the respective journals as well as their number of citations.

Table 2: Top10 journals for Green Innovation Research

Rank	Journal	TP	TP (%)	CS 2020	TC	The most cited article	Times cited	Publisher
1	Journal Of Cleaner Production	98	8.96	13.1	4388	The drivers for contractors' green innovation: An industry perspective	257	Elsevier
2	Sustainability Switzerland	96	8.78	3.9	1341	Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers	253	Multidisciplinary Digital Publishing Institute (MDPI)

Rank	Journal	TP	TP (%)	CS 2020	TC	The most cited article	Times cited	Publisher
3	Business Strategy and The Environment	49	4.48	10.3	1835	Green Product Innovation: Where we are and where we are Going	200	Wiley-Blackwell
4	International Journal of Environmental Research And Public Health	25	2.29	3.4	186	Assessing regional differences in green innovation efficiency of industrial enterprises in China	30	Multidisciplinary Digital Publishing Institute (MDPI)
5	Technological Forecasting And Social Change	17	1.55	12.1	978	Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices	206	Elsevier
6	Energy Policy	13	1.19	10.2	793	Going hybrid: An analysis of consumer purchase motivations	285	Elsevier
7	Journal Of Environmental Management	13	1.19	9.8	93	Environmental regulation and energy-environmental performance—Empirical evidence from China's non-ferrous metals industry	24	Elsevier
8	Environmental Science And Pollution Research	12	1.10	5.5	119	A grey DEMATEL-based approach for modeling enablers of green innovation in manufacturing organizations	31	Springer Nature
9	Energy Economics	10	0.91	10	165	The impact of green innovation on energy intensity: An empirical analysis for 14 industrial sectors in OECD countries	78	Elsevier
10	Journal of Business Ethics	10	0.91408	9	2250	The influence of green innovation performance on corporate advantage in Taiwan	755	Springer Nature

1.3.4. Top cited articles

This section presents the top 10 cited studies found in the Scopus. The keyword “green innovation” in title, abstract, and keywords was used as a query string to identify the published literature. The most cited article with 755 total citations (TC) is “The influence of green innovation performance on corporate advantage in Taiwan” authored by Chen et al., (2006). The second most cited article in Scopus is “Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective” with 670 citation whose author (Geels, 2014) argue that while policy makers highly hope that green innovation will bring about low carbon transitions, there is a need to focus on new innovations to prevent the

existing fossil fuel reserves from being burned or on stimulating the widespread adoption of carbon capture and storage. The top third highly cited article is “The driver of green innovation and green image - Green core competence” with 570 citations. In this article the authors (Chen, 2008) builds that a firms' green core competencies are linked to their green innovation performance and green image. The rest of the highly cited articles along with their respective citations are mentioned in figure 4.

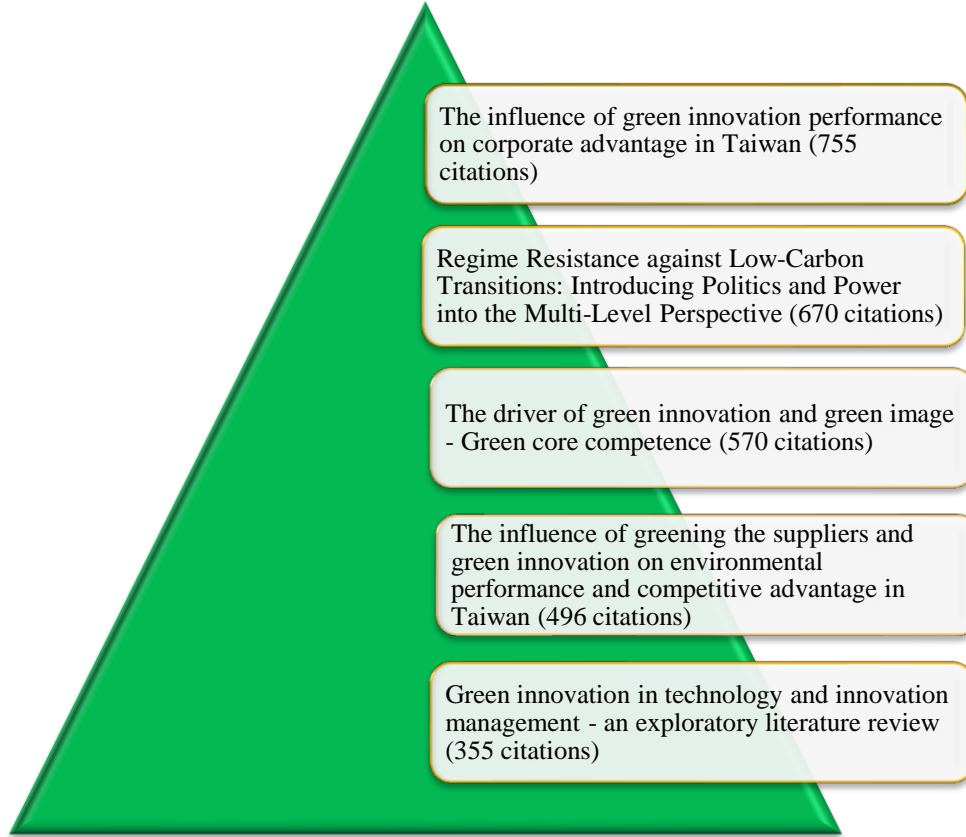


Figure 4: Most cited articles in Green Innovation research

1.3.5. Most Prolific Authors

Our analysis revealed that the top author in the green innovation fields is Chen, Yushan with total 10 publications and most citations that is, 1999 citations. It is followed by Chang, Chinghsun with 8 publications and 700 citations. Li, Dayuan is third place with 7 publications and 444 citations. Sun, Jun

Table 3: Most prolific authors in Green Innovation Research

Rank	Author	Total publication	Scopus Author ID	Year of 1st Publication	h-index	Current affiliation	Total citation
1	Chen, Yushan	10	14830001100	2006	31	National Taipei University, Taipei, Taiwan	1999
2	Chang, Chinghsun	8	26022301000	2009	20	National Taiwan University, Taipei, Taiwan	700
3	Li, Dayuan	7	47861064000	2017	15	Central South University, Changsha, China	444

Rank	Author	Total publication	Scopus Author ID	Year of 1st Publication	h-index	Current affiliation	Total citation
4	Sun, Jun	7	55716202200	2016	15	University of Texas Rio Grande Valley, Brownsville, United States	93
5	Yang, Zhaojun	7	57193136154	2016	10	Xidian University, Xi'an, China	93
6	Albort-Morant, Gema	6	56957208700	2016	13	Universidad de Sevilla, Sevilla, Spain	371
7	Cooke, Philip N.	6	7201726876	2009	41	Western Norway University of Applied Sciences, Bergen, Norway	120
8	Dangelico, Rosa Maria	6	21833539400	2011	20	Sapienza Università di Roma, Rome, Italy	527
9	Feng, Taiwen	6	25930958400	2016	21	Harbin Institute of Technology at Weihai, China	150
10	Jermsittiparsert, Kittisak	6	57214268798	2019	40	Dhurakij Pundit University, Bangkok, Thailand	16

Yang, Zhaojun also has 7 publications each, but their citation count is quite low as compared to Li, Dayuan. The top 10 authors along with their total publications, citations, h index and current affiliation are listed in table 3.

1.4. Bibliometric Analysis

1.4.1. Co-authorship countries

In order to identify the main collaborative networks between countries, a Co-authorship analysis of countries was performed. The size of the node indicates the number of collaborations, and as shown in Figure 5, the most collaborative countries are China, United states and United Kingdom. Our results revealed that China has the most collaborative publications and has a total link strength (TLS) with 5708 citations. The number of published documents of China is also by far the most (n=443) as compared to the other countries. United States is the second country with most collaborative publication and has TLS of 72, with 84 published documents and 1667 citations. The third important country with most collaborative research is United Kingdom having TLS of 70, having 75 published documents and 3299 citations. It is interesting to note that developing countries like Pakistan and Malaysia also made it to the list of top 10 countries involved in collaborative research. Also, these are the only Asian countries involved in green innovation research that made it to the top 10 list in terms of publication. Similarly, the top 10 most collaborative countries with highest number of published documents are listed in Table 4.

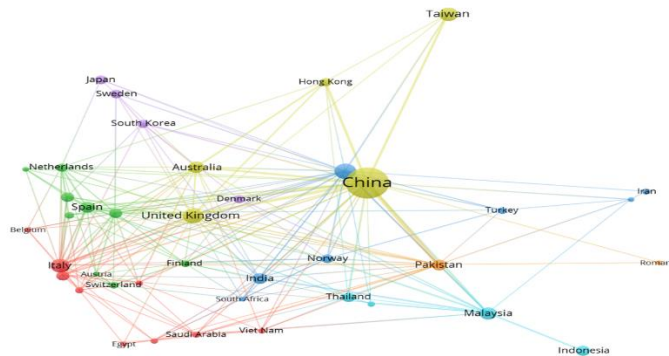


Figure 5: Co-authorship analysis of countries, Network Visualisation view in Vos Viewer; figure available online at: https://app.vosviewer.com/?json=https://drive.google.com/uc?id=1Q5_LRRw2k88a4qndaiL6-Fzdo3rzfwy3

Table 4: Top countries doing collaborative research on Green Innovation

Country	Number of documents	Total citations	TLS
China	443	5708	137
United States	84	1667	72
United Kingdom	75	3299	70
Pakistan	38	392	52
Italy	59	2104	42
Australia	40	1442	35
Malaysia	48	717	35
France	26	944	33
Spain	37	1624	30
Germany	25	1100	25

1.4.2. Co-occurrence of author keywords

Through bibliometric analysis we also thrived to determine the merging topics and keywords related to the green innovation research. Co-occurrence analysis represents the occurrence of items in a particular document. In Vos viewer we set the criteria of the minimum number of occurrences per keyword to 5 as a result we obtained 107 author keywords out of 2649. After merging the similar or identical keywords and removing the irrelevant keywords we obtained 91 keywords related to the green innovation research. The keywords in yellow colour are the ones that have been recently discussed in the green innovation field or we could say that these are the emerging topic in the green innovation research. The results of our analysis revealed that innovation, sustainability, sustainable development, environmental regulations, and competitive advantage are the top five keywords mostly associated with green innovation research (figure 6).

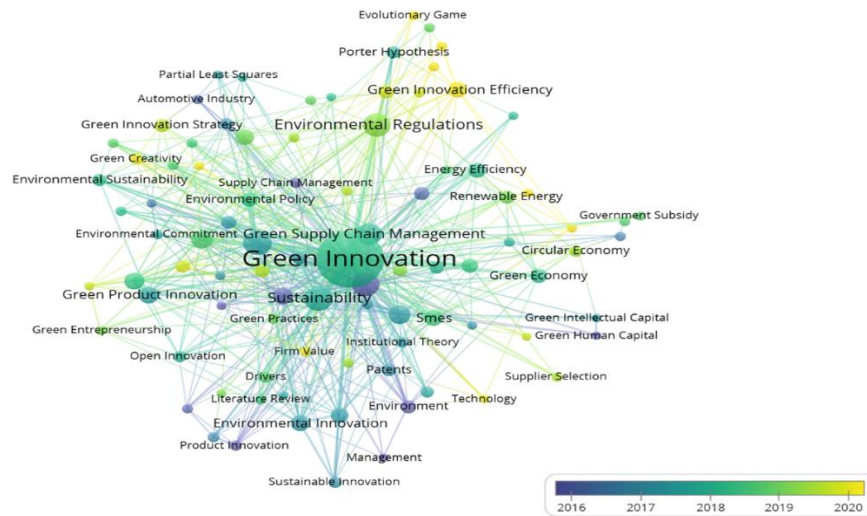


Figure 6: Co-occurrence analysis of author keywords, figure available online at:

<https://app.vosviewer.com/?json=https://drive.google.com/uc?id=14Iwfw3HVadl0N94L-iaq2u7u5kFm5oVF>

Some of the other hot topics in the green innovation research areas are environmental performance, financial performance, green supply chain management, green product and process innovation, green management, SMEs, eco-innovation, environmental policy, financial performance, manufacturing industry, green innovation performance and absorptive

capacity. It is evident from the hot topics in the field that green innovation has a significant relationship with financial, marketing, environmental and green innovation performance of a firm as well as provides competitive edge to the firms over its competitors (Tariq et al., 2017). We can determine that these are the most researched keywords in green innovation research based on the number of occurrences and total link strength (TLS). The top 20 keywords, their number of occurrences in the selected dataset and their TLS is shown in table 5.

Table 5: Top 20 hot topic in Green Innovation research

Keyword	Occurrences	TLS
Green Innovation	475	548
Innovation	55	114
Sustainability	60	110
Sustainable Development	59	106
Environmental Regulations	53	84
Competitive Advantage	31	70
Environmental Performance	33	68
Green Supply Chain Management	44	68
Green Process Innovation	25	52
Green Product Innovation	26	50
Environmental Innovation	22	49
Green Management	25	49
SMEs	22	48
Eco-Innovation	20	45
Environmental Policy	17	31
Financial Performance	12	31
Manufacturing Industry	17	29
Environment	15	28
Green Innovation Performance	22	28
Absorptive Capacity	10	25

We've also found the least frequently used keywords in the literature. We assume that these are the areas where there has been limited research to date, and that future academics should concentrate their efforts in these areas to fill the gap in the literature. These keywords are listed in table 6 along with their number of occurrences and total link strength.

Table 6: Emerging areas/keywords in Green Innovation research

Keywords	Occurrences	TLS
Green Human Capital	5	9
Green Innovation Practices	5	9
Green Innovation Strategy	13	9
Green Patent	6	9
Green Development	6	8
Knowledge Management	5	8
Supplier Selection	6	8
Energy Consumption	5	7
Recycling	6	7
Data Envelopment Analysis	5	6
Government Subsidy	7	6
Green Innovation Capability	6	6
Green Performance	5	6
High-Tech Industry	5	6
Technological Innovation	6	6

Keywords	Occurrences	TLS
Evolutionary Game	7	5
Game Theory	6	4

It is evident from table 6 that green human capital, green innovation practices and strategy, green patent, knowledge management, supplier selection, energy consumption, recycling, data envelopment analysis, government subsidy, green innovation capability, green performance, high-tech industry, technological innovation, evolutionary game and game theory are some the areas which have limited research available with respect to green innovation. These open avenues of future researchers to conduct research on the above-mentioned areas and observe the results.

1.5. Conclusion

The field of green innovation has experienced a substantial growth in research publications since 1995 especially the past 5 years that has reflected a noteworthy impact on the literature. Green innovation is an emerging topic and holds great importance for academicians and practitioners because of its relevance to saving the environment as well as making economic profits. Our finding revealed that China (444 publications), the United States (86 publications), and the United Kingdom are the top three most producing countries (75 publications). Journal Of Cleaner Production is the top journal for green innovation research. This study has also identified the top 10 authors and most cited publications as well as the most productive institutions in green innovation area. Through co-authorship analysis of countries, we found that are China, United States and United Kingdom are the countries with most collaborative research. Through co-occurrence of keywords analysis, we determined the hot topics in the green innovation field which are innovation, sustainability, sustainable development, environmental regulations, and competitive advantage. We also suggested some inviting areas for further research direction to provide guidelines or future researchers enabling them to focus their efforts in such areas and fill the gaps in the research

1.6. Limitations and Future Directions

In the literature, four terms are used interchangeably to describe innovations that contribute to or are intended to reduce an organization's negative environmental impact: "green," "environmental," "sustainable," and "eco". However, to keep our emphasis on solely green innovation, the collected data was confined to the keyword "green innovation" used in the titles, abstracts, and author keywords. Future studies could combine the literature of all the four terminologies and perform a similar analysis and see if there are inconsistencies. Future researchers could also conduct a study of existing green innovation themes and track their evolution through time. In this study, the articles selected for analysis are limited to Scopus database only. Future researchers may conduct similar research using other databases such as google scholar and web of science to gather more data and gain a better understanding of the subject. This study aimed to present general overview of the publication trend over time so didn't focus on a specific time period. Future studies could perform a review of a particular time frame instead of just giving a general overview and determine the emerging themes and hot topics and in the green innovation field.

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