BIBLIOMETRIC ANALYSIS: THE ROLE OF BIG DATA IN ADVANCING GREEN PRODUCT INNOVATION

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Abstract. This study aims to conduct a bibliometric analysis to examine the role of big data in driving green product innovation for achieving sustainable development. By analyzing publication trends, citation growth, research disciplines, country contributions, and author networks, this research provides valuable insights into the progression of studies within this domain. This study employed a bibliometric approach to analyze scientific publications related to big data and green product innovation. Data were sourced from the Scopus database, encompassing publications from 2015 to 2024. The research assesses key bibliometric indicators, including citation trends, document types, and distribution of subject areas, international collaborations, and prominent authors in the field. The results reveal a notable increase in research focus on big data-driven green product innovation, particularly following 2020, as demonstrated by the rising number of citations. The majority of the published works comprise journal articles (46%) and conference papers (26%), showcasing a robust interest from both academic and industrial sectors. The principal research fields identified are engineering, business, and computer science, underscoring the technological and economic facets of green product innovation. Additionally, strong international collaborations are evident, with significant contributions from Asia, North America, and Australia. The authorship distribution indicates a diverse and cooperative research landscape. The findings offer valuable insights for researchers, policymakers, and industry practitioners on utilizing big data for sustainable production. Understanding research trends and collaboration networks can enhance resource allocation and strategic decision-making for sustainable industrial transformation. This study advances the literature by delivering a comprehensive bibliometric analysis of the role of big data in green product innovation. The insights derived from this analysis can guide future research, particularly in integrating interdisciplinary approaches, enhancing the application of big data, and promoting collaboration to achieve sustainable development goals.
Keywords: *bibliometric analysis, big data, green production, sustainable development, research collaboration, innovation*

Introduction

In today's digital age, there is a substantial generation of data, commonly called big data. Big data refers to a vast and continually expanding collection of information collected from various sources, including mobile transactions, internet clicks, and internal company data from sales and purchase transactions (George et al., 2014). This data can exist in many forms, such as text, photos, audio, and video shared on social media platforms. For instance, consumer reviews of specific products and feedback regarding their benefits can reveal social trends that are valuable for developing products and services. When used effectively, big data can significantly lower costs, accelerate the completion of computing tasks, and drive innovation in new products and services (Davenport and Dyché, 2013). Companies can leverage big data to gain deeper insights into their products, customers, and markets (McKinsey Global Institute, 2011). Research (Zhan et al., 2017) shows that analyzing big data can enhance product innovation capabilities and improve supply chains, ultimately leading to a competitive

advantage. Green product innovation is a multifaceted process that addresses three key environmental aspects: materials, pollution, and energy, each of which has distinct impacts throughout a product's life cycle (Dangelico and Pujari, 2010). This innovation is largely driven by internal factors such as cost reduction, opportunities for competitive advantage, enhancement of reputation, market benefits, and the potential for improved product quality. Significant external influences include environmental regulations, stakeholder pressure, and market demand (Dangelico, 2017). The implementation of green product innovation is integral to the framework of sustainable business, rooted in the principles of sustainable development. This framework highlights the interconnectedness of people, profits, and planet, reflecting the concept of sustainability known as the "triple bottom line." This approach emphasizes the importance of economic prosperity, environmental quality, and social justice (Elkington, 1997).

This research will examine the role of big data in green product innovation to promote sustainable development. Sustainable development is defined as fulfilling the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987). Product innovation development pays attention to environmental and social aspects that can provide economic benefits for the company. Big data analysis plays a crucial role in achieving sustainable business practices by offering real-time data on energy consumption, carbon emissions, and waste management resulting from production processes. Additionally, big data can analyze consumer demand for environmentally friendly products, market trends, supplier networks, and operational efficiencies to support sustainable business initiatives. Big data analytics serves as a vital instrument in advancing sustainability. Research by (Waqas et al., 2021), highlights that big data analytics plays a significant role in achieving competitive advantage and improving environmental performance through green innovation and sustainable human resource management (HRM) practices. This study specifically examines the impact of big data on driving green product innovation to foster sustainable development.

Literature review

Big Data

Big data embodies a comprehensive approach to managing processes and analyzing various dimensions of data for actionable insights (Tan et al., 2015). It is generated from a wide array of sources and includes diverse types, such as GPS data, blog entries, social media posts, photos, videos, online sales transactions, and graphics, among others. Each data point carries intrinsic value that can be extracted through algorithms, analytics, and various advanced techniques. The key dimensions of big data consist of: volume (the immense quantity of data generated.), variety (the diverse formats of data, encompassing both structured and unstructured types), veracity (the accuracy and reliability of the data) and velocity (the swift pace at which data is created and processed). A systematic review conducted by (Fosso Wamba et al., 2015) analyzed big data research from 2008 to 2012, identifying 125 articles that emphasize the significant potential of big data for value creation. The findings clearly outline five primary pathways through which big data generates value: (1) Automating decision-making processes to either replace or support human judgment with algorithms; (2) Driving innovation in business models, products, and services; (3) Enabling experimentation to identify needs, reveal variability, and enhance performance; (4) Effectively segmenting

populations to customize actions; and (5) Increasing transparency across operations. Big data is vital for businesses, as companies manage a substantial amount of both structured and unstructured data that needs to be organized for analysis and informed decision-making. This encompasses communication data from emails, phone calls, and instant messages, along with transactions with suppliers and various data necessary for compliance with government regulations. The rapid pace of big data can enhance new product development, reducing costs and enabling swift feedback. This prompt feedback is crucial for the Research and Development (R&D) department in driving innovation in product development and achieving a competitive advantage (Zhan et al., 2017).

Green product innovation

Green product innovation refers to the development of new products and the implementation of innovative production methods (Rodrigues and Franco, 2023; Bai et al., 2019). This concept aligns with the perspective of Porter and Van Der Linde (1995) who argue that innovation is a response to environmental policies. Such innovations can be classified into two main categories: efforts to reduce pollution by minimizing or eliminating the use of hazardous materials, and advancements in product development that arise from improved material substitutions, decreased energy consumption, and the transformation of waste into valuable resources. Green product innovation is defined as one that has a lower environmental impact compared to its predecessors. It typically features longer usability, lower emissions, and reduced energy consumption during use. Additionally, it is free from toxic substances and can be recycled (Dangelico and Pujari, 2010). Green product innovation is a multifaceted process that prioritizes three key environmental considerations: materials, energy, and pollution. This type of innovation sets itself apart from conventional products by emphasizing the careful selection of raw materials that diminish environmental harm, lower energy use, and facilitate recycling, reuse, or degradation. Green product innovation considers environmental regulations, stakeholder interests, and market demands. The decision-making process pertaining to green innovation is of paramount importance for organizations, as it necessitates a substantial commitment from management to embrace the principles of sustainability. Moreover, the utilization of big data significantly contributes to the effectiveness of these decisions.

Materials and Methods

This research utilizes quantitative methods, specifically bibliometric analysis, which is widely adopted in business research, including business strategy (Kumar et al., 2021). Bibliometric analysis is a thorough and effective approach for exploring and analyzing extensive amounts of scientific data (Donthu et al., 2021). Data for this study were obtained from Scopus, the largest peer-reviewed database globally, recognized for its utility in big data analysis (Kumar et al., 2021). The keywords employed in Scopus were "big data AND green product innovation," focusing on English-language journal articles published between 2015 and 2024 within the fields of business, management, and accounting. This search resulted in a total of 27 articles out of 58 documents, which included conference papers, books, book chapters, and reviews. Furthermore, Publish or Perish (PoP) software was used to conduct additional searches for articles relevant to the keywords of this study. The data analysis consists of bibliometric methods

categorized into two primary types. The first type, performance analysis, evaluates the contributions of various research entities within a specific field, including authors, journals, institutions, and countries. The second type, science mapping, examines the relationships among these research entities, employing citation analysis as an indicator.

Results and Discussion

Data overview

Based on the search results using the keywords TITLE-ABS-KEY (big data) AND (green product innovation) from 2015 to December 2024, there are a total of 58 documents. Out of these, 36 documents have received 1,856 citations, resulting in an h-index of 14 from 50 authors. According to the PoP metrics, the 58 documents collectively have 1,856 total citations, with an average of 185.60 citations per year. Each paper has been cited an average of 32 times, maintaining an h-index of 14. *Table 1* displays the metrics that reflect publication performance from 2015 to 2024. The author has published a total of 58 papers, which have collectively received 1,856 citations. This results in an average of 185.60 citations per year and 32.00 citations per publication. Author productivity is represented by a ratio of 49.99 publications per author, with 0.86 authors per publication. The bibliometric index reflects an h-index of 14, meaning there are 14 publications that have each been cited at least 14 times. Additionally, the g-index is recorded at 43, indicating that the 43 most cited publications have received a total of 1,849 citations. The normalized index hl is 14, while hA is 11, indicating that the publication has an overall impact, even though the lead author does not always dominate the citation contributions. The data also shows the number of publications with accumulated citations above certain thresholds (ACC≥1, 2, 5, 10, 20), with the highest count being 26 publications having at least one citation. Overall, this data suggests that the publications during this period have made a significant scientific impact based on citation trends.

Table 1. *Citation Metrics.*

Metrics	Values
Publication years	2015-2024
Citation years	10 (2015-2024)
Papers	58
Citations	1856
Cites/year	185,60
Cites/papers	32,00
Cites/author	1855.00
Papers/authors	49,99
Authors/papers	0,86
h-index	14
g-index	43
hl,norm	14
hl,annual	1,40
hA-index	11
Papers with ACC ≥ 1	26
Papers with ACC ≥ 2	22
Papers with ACC ≥ 5	15
Papers with ACC ≥ 10	12

Papers with ACC ≥ 20	6

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Publication, citation and trend

There were 58 publications from 2015 to 2024 focused on big data and green product innovation. The volume of publications is a crucial indicator of the developmental trends in specific fields of scientific research, while citation counts reflect the impact of these works (Yuan and Sun, 2022). Notably, in 2024, research in this area achieved the highest citation count over the past decade, reaching a total of 732 citations. *Figure 1* illustrates the trend in the number of citations per year from 2015 to 2024. The data reveals that the number of citations has experienced exponential growth, especially in recent years. During the initial period (2015-2018), citations were relatively few, recording values of 0, 2, 3, and 8, respectively. However, starting in 2019, there was a notable surge, with citations reaching 43. This upward trend continued in 2020 with 122 citations and in 2021 with 138 citations.. The growth became even more pronounced after 2022, with citations leaping to 306, then to 460 in 2023, and culminating at 739 citations in 2024. This trend suggests that the publications are attracting greater attention from the academic community, signifying an enhancement in the scientific impact of these works over time. Research on big data and green product innovation demonstrates a positive trajectory since 2019, with both the volume of publications and citations steadily increasing through 2024.

***Table 2**. Publication based on year.*

Year	Number of document
2024	21
2023	8
2022	7
2021	5
2020	3
2019	6
2018	3
2017	1
2016	1
2015	3
Total	58

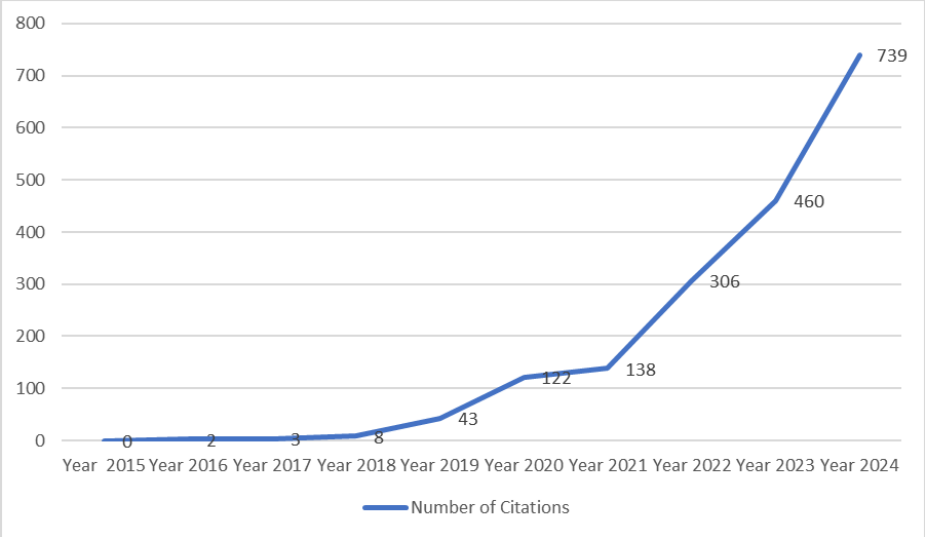

Figure 1. *Number of citation.*

Document types are classified into several categories: articles, conference papers, conference reviews, reviews, book chapters, books, and erratums. *Figure 2* presents a doughnut diagram illustrating the distribution of these published document types. Among the total publications, scientific articles comprise the largest portion, with 27 documents or 46%, indicating that journals are the predominant medium for research dissemination. Conference papers also account for a substantial share, totaling 15 documents (26%), reflecting active engagement in academic presentations. Other document types include reviews (9 documents or 15%), conference reviews (5 documents or 8%), in addition to book chapters (1 document or 2%) and books (1 document or 2%). Furthermore, there is 1 document categorized as an erratum, which serves to correct a prior publication. This distribution underscores a diverse publication strategy, with journal articles and conference papers being the primary channels for sharing research findings.

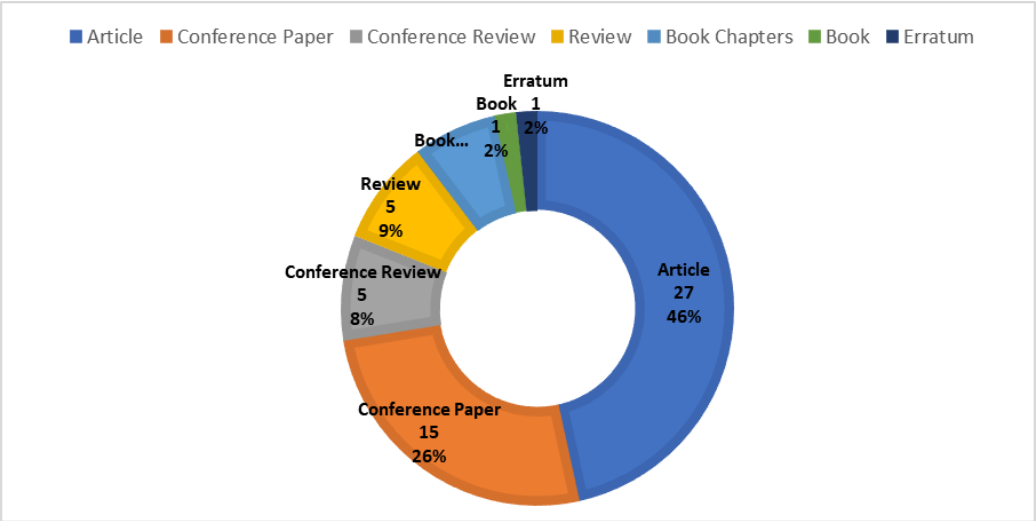

Figure 2. *Document type.*

The citation overview from Scopus presents a detailed account of articles published from 2015 to 2024. In total, there are 36 articles that have garnered 1,840 citations, resulting in an h-index of 13. However, several highly cited articles that do not pertain to big data and green product innovation have been intentionally excluded from the article table. For instance, the work of (Melander and Pazirandeh, 2019) has 95 citations but focuses solely on green product innovation without any connection to big data. Similarly, the article (Fontoura and Coelho, 2022), titled "How to Boost Green Innovation and Performance through Collaboration in the Supply Chain: Insights into a More Sustainable Economy," has 51 citations and is omitted for the same reason, as it does not directly address big data. Another significant article, "Measuring and Evaluating SDG Indicators with Big Earth Data," (Guo et al., 2022) has received 80 citations but is also left out of Table 3. This exclusion is due to its focus on analyzing the use of big earth data for evaluating Sustainable Development Goal (SDG) indicators rather than on green product innovation. Consequently, the articles featured in *Table 3* specifically explore the role of big data in facilitating innovation in green products for sustainable development.

***Table 3**. Number of articles with the highest number of citations.*

Author	Title	Citation	Journal
El-Kassar (2019)	Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices	782	Technological Forecasting & Social Change
Bag et al. (2020)	Big data analytics as an operational excellence approach to enhance sustainable supply chain performance	438	Resources, Conservation and Recycling
Yang et al. (2021)	Green Internet of Things and Big Data Application in Smart Cities Development	50	Complexity
Fantke et al. (2021)	Transition to sustainable chemistry through digitalization	50	Chem
Ardito et al. (2020)	The interplay between technology characteristics, R&D internationalisation, and new product introduction: Empirical evidence from the energy conservation sector	25	Technovation
Halbusi et al. (2023)	The Role of Green Digital Learning Orientation and Big Data Analytics in the Green Innovation-Sustainable Performance Relationship	16	IEEE Transactions on Engineering Management
Ortega-Requena and Rebouillat (2015)	Bigger data open innovation: Potential applications of value-added products from milk and sustainable valorization of by-products from the dairy industry	15	Green Chemistry

Green innovation can be successfully achieved when top management is committed to implementing environmentally friendly practices (El-Kassar, 2019). This commitment allows management to effectively integrate Big Data across various organizational processes, particularly those related to environmental initiatives. In parallel, Bag et al. (2020) found that the management capabilities of big data analytics significantly influence the development of green product innovation and the outcomes of sustainable supply chains. The application of big data in green product innovation can extend to various fields, such as green internet technologies (Yang et al., 2021), the sustainable chemical industry (Fantke et al., 2021), and general technology (Ardito et al., 2020). Furthermore, green innovation is positively correlated with sustainable performance, and this correlation strengthens when there is a high orientation towards green digital learning. Halbusi et al. (2024) also highlights that big data analysis has a significant three-way interaction effect on sustainable performance.

The leading fields of study, based on publication numbers, are engineering with 22 publications, followed closely by business with 21, and computer science with 18. Notably, both computer science and social science made significant contributions, with

18 and 15 publications, respectively, highlighting their importance in multidisciplinary research. Agriculture and environmental science each accounted for 7 publications, while other areas such as decision sciences produced 6 publications, and both economics and energy contributed 4 publications each. Medicine, biochemistry, and earth science generated between 2 to 3 publications each. This distribution demonstrates a pronounced emphasis on engineering and business in research, while still reflecting a range of other disciplines. It indicates that green product innovation—focused on crucial indicators such as materials, energy, and pollution—can be relevant across various fields. Moreover, big data is closely linked to computer science and engineering, establishing its significance in all academic disciplines.

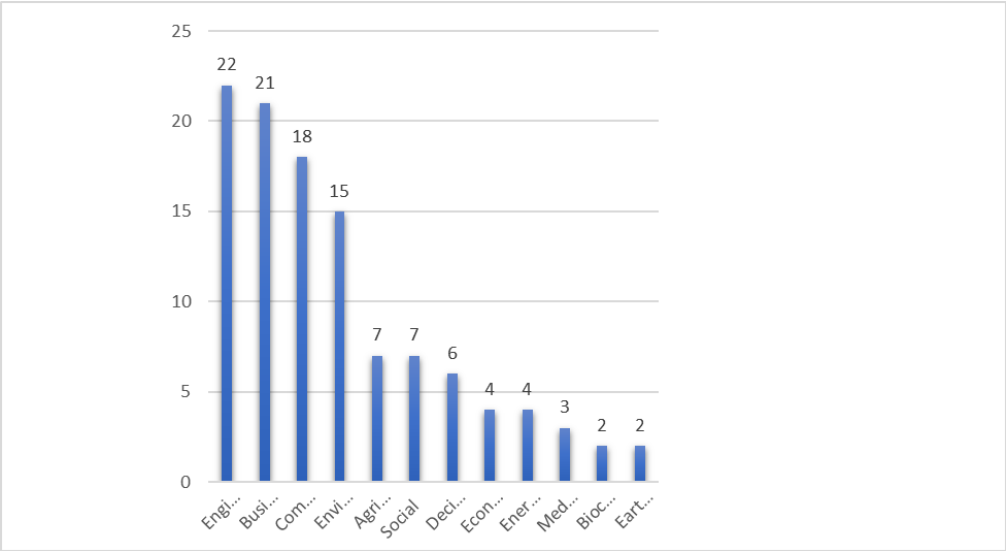

Figure 3. *Documents by subject area.*

Number of documents and country distribution

This map depicts the distribution of countries according to the number of articles included in Scopus. China leads with 20 articles, followed by India with 6 articles and Italy with 5. Other countries such as France, Canada, Malaysia, Pakistan, Spain, and Sweden each have 3 articles. Furthermore, Australia, Egypt, and Germany each have contributed 2 articles. This distribution pattern highlights the international collaboration in the research conducted, revealing a dominance of contributions from certain countries. This suggests that the research has a global influence and is recognized within the international academic community. Among the 58 documents analyzed by author contributions, only three authors have published two documents each, while the remaining authors are credited with only one document. According to Scopus data, Al-Shobul, M.A. has four documents as the main author published between 2014 and 2023, with an average citation count of 44. Related to big data and green product innovation, (Al-Shboul, 2024) article is titled *"Do reliable big and cloud data analytics capabilities in manufacturing firms' supply chains boost unique comparative advantage? A moderated-mediation model of data-driven competitive sustainability, green product innovation, and green process innovation in the North Africa region"*, which has yet to receive any citations. Another prominent author is Singh, R.K who has published 16 documents as the main author according to Scopus data from 2014 to 2023, with an

average citation count of 26. His most recent article, also related to big data and green product innovation, was published in 2024 and has not garnered any citations thus far. The distribution pattern reveals that contributions to publications in the examined research fields are generally well-distributed among various authors, with no individual significantly dominating the contributions. This indicates a collaborative balance in the production of scientific work, although some active authors do have multiple publications.

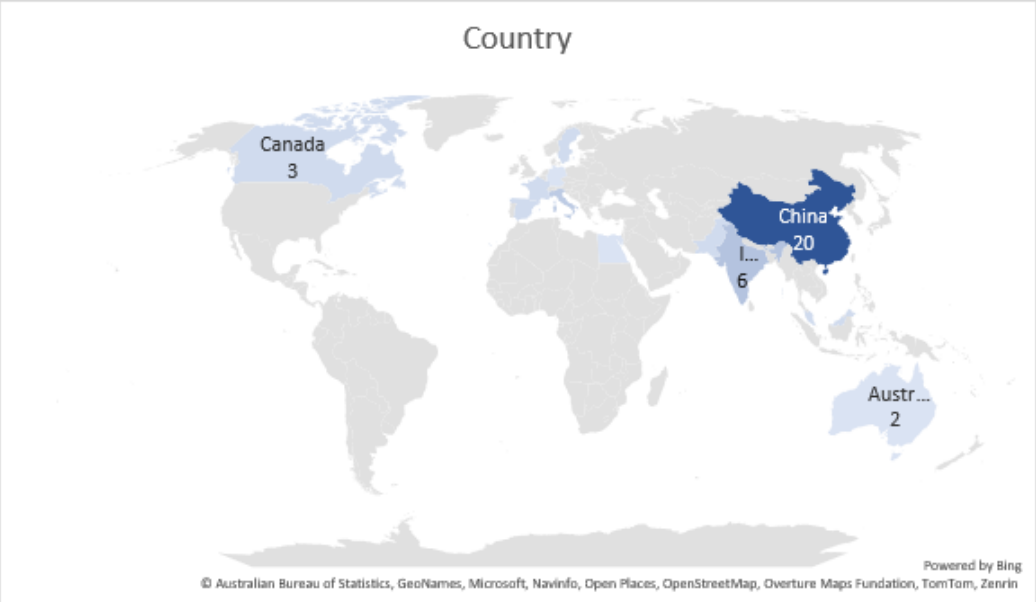

Figure 4. *Country distribution of authors.*

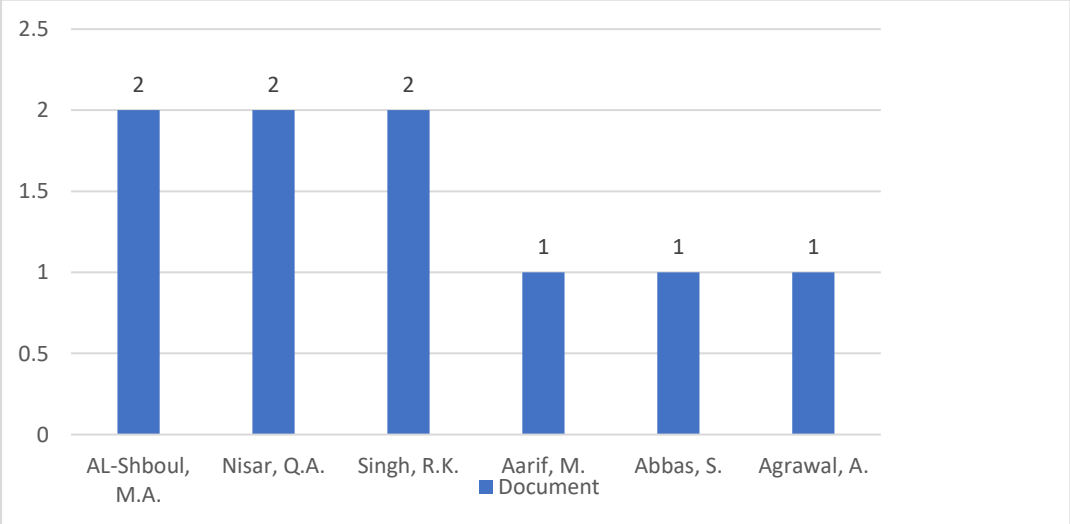

Figure 5. *Number of documents per author.*

Conclusion

This research aims to demonstrate the role of big data in promoting green product innovation through a bibliometric analysis of the Scopus database, covering the years

2015 to 2024. The research process involved designing a study and retrieving data from Scopus over a ten-year period, resulting in a total of 58 documents analyzed through bibliometric methods. The findings indicate a growing interest in the intersection of big data and green product innovation, starting from just 3 documents in 2015 and experiencing a significant spike in 2019. Although there was a decline in 2020, the number of publications steadily increased, reaching a total of 21 documents by 2024, with the highest citation count at 739. Of the 58 documents analyzed, journal articles comprised 46%, while conference papers accounted for 26%. This distribution illustrates that the topic has garnered significant attention in both scientific journals and academic conferences. The three primary subject areas identified in the research were engineering, business, and computer science, highlighting the relevance of the study to technological and industrial advancements. There is also evidence of international collaboration, as indicated by the distribution of publications by country. China ranked first with 20 documents, followed by India with 6 and Italy with 5. Citation analysis revealed that the article by (El-Kassar, 2019) received the highest number of citations, totaling 789, followed by Bag et al. (2020) with 438 citations. The data suggests that publication output is relatively evenly distributed among multiple authors, with no single individual dominating the field. The findings emphasize the role of big data in advancing green product innovation for sustainable development. Future research could explore the factors influencing citation growth, particularly the impact of international collaboration on research quality. Additionally, employing big data and machine learning techniques in bibliometric analysis could help uncover more complex patterns in scientific publications. Lastly, investigating the effectiveness of various publication platforms in enhancing research impact presents an intriguing avenue for further study.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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