Downstream Economics to Support Sustainable Industrial Growth: Trends and Insights from Bibliometric Analysis

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Abstract: - This article aims to examine trends and gain insights from bibliometric studies on downstream economics and its role in supporting sustainable industrial growth. The analysis covers 19,816 articles from the Scopus database published between 1972 and 2025. We used Bibliometrix, VOSviewer, and CiteSpace to identify main trends. We found that topics such as 'biomass,' 'microalgae,' and 'life cycle assessment' are becoming more important, highlighting a move toward bioenergy and renewable resources to reduce industrial environmental impact. The results show that adopting circular economy models and improving supply chain management are key to spreading these innovations. Taking an interdisciplinary approach is important to connect new technologies with policy and to address the challenges of using renewable energy, circular economy ideas, and ecosystem restoration.

Key-Words: - Bibliometric, Downstream economics, Sustainable industrial growth, Circular economy, Bioenergy, Renewable resources

Received: May 21, 2026. Revised: June 22, 2026. Accepted: July 23, 2026. Published: September 14, 2026.

1 Introduction

There is growing global attention on sustainable development, which has increased interest in sustainable industrial growth, especially in downstream activities. These activities happen after the first stage of manufacturing or extraction and involve turning raw materials or semi-finished goods into finished products for consumers. For countries with many resources, downstream activities are important for driving industrial development and supporting sustainability. Yet, the link between downstream activities and sustainable development has not been widely studied. This study attempts to fill that gap by analyzing the literature on the downstream economy and its role in sustainable industrial growth. By looking at trends, challenges, and future directions, the study presents insights into how focusing on downstream activities can help achieve sustainable economic growth.

Downstream activities are especially important in developing countries, where industrial growth usually depends on exporting raw materials. To achieve environmentally sustainable industrial growth, it is necessary to balance economic development, environmental protection, and social fairness. This study looks at how downstream activities can help align industrial policies with environmental targets. Using bibliometric analysis, it identifies key research, important publications, and major trends, giving a broad overview of work in this area.

Besides reviewing academic discussions, this study points out the main challenges that industry and policymakers face when trying to achieve sustainable industrial growth through downstream activities. These problems include limits in technology, regulatory obstacles, and the need for new ideas in policy and practice. Bibliometric analysis helps find where research is focused and where gaps exist. The study attempts to guide future research and policy by suggesting strategies that connect downstream economic activities with sustainable growth.

1.1 Background and Importance of Downstream Activities in the Economy.

Downstream economic activities focus on adding value and increasing output at the end of the supply chain, mainly in distribution and retail. These activities affect pricing, investment decisions, and overall profits in the supply chain. For instance, when retailers work together at the downstream level, it may sometimes lead to lower profits and lower quality for products that need a lot of development, illustrating the need for a better strategy in downstream activities [1]. In online retail, sharing information downstream helps suppliers set up commission channels, pick better sales channels, and reach more customers [2]. Competition from imports in the downstream sector can also change the financial structure of upstream firms, making them choose safer financial policies to manage risks from changes downstream [3].

Micro, small, and medium enterprises (MSMEs) play a key role in the value chain, especially in developing areas, where they help ensure food security and provide jobs in downstream sectors. These businesses are often left out of policy discussions, but they are important for food distribution in places like Africa and South Asia, so better infrastructure and regulations are needed to help them grow [4]. When competitors work together at the end of the supply chain, it shows how important good information management is. Companies use differences in information to get better deals and improve buying processes, which helps them stay competitive [5]. In general, downstream economics are important for making supply chains more efficient, building competitive advantage, and facilitating sustainable growth in different industries.

1.2 Overview of Downstream Economics in Industrial Sectors

In general, in all industrial sectors, downstream economy is defined as activities that transform raw materials into final products, which will ultimately make the economy grow sustainably. The logistics industry is a key part of this process, supporting manufacturing by moving goods efficiently.

Policies such as "Made in China 2025" have improved production and services in the logistics sector, showing the importance of innovation for high-quality development [6]. The connection between water and energy is also key, especially within industries such as steel, chemicals, and food, where efficient use of these resources can save money and support sustainability. This illustrates the need for a combined approach to managing resources, which is important for downstream processes [7].

In Europe, industrial energy cooperation in industrial zones shows that sharing services and energy use can help achieve sustainable and economic development. This method assists in overcoming technical, economic, and social challenges, encourages better energy use, and reduces greenhouse gas emissions, which is important for downstream economic activities [8].

In India, we can observe that programs such as "Make in India" and "Atmanirbhar Bharat" have been able to drive manufacturing to grow in a "green" manner while also reducing dependence on imports. These programs encourage and create new manufacturing ventures, support innovation, and promote environmentally friendly practices that are crucial for downstream economic activities [9].

In China, especially in the textile industry, combining environmental policies with efforts to improve productivity has increased green performance without hurting growth. This balance is important for managing downstream economic activities while protecting the environment, as shown by data from 1998 to 2012 [10]. These strategies highlight the need for a broad approach to effective downstream economic activities in industry.

2 Research Objectives and Scope

This study explores how the downstream economy relates to environmentally sustainable industrial development using a detailed bibliometric analysis. The downstream economy, which adds value to raw materials through local processing and manufacturing, is especially important for developing countries that want to get the most from their natural resources.

The study illustrates the main trends in the scientific literature on these topics, looking at how academic discussions have changed in response to international environmental objectives and industrial innovation. Through analyzing publication patterns, citation networks, and key works, the study reviews the research landscape on the downstream economy and its role in supporting long-term industrial growth.

Along with mapping current research trends, this study looks at the main challenges that render it hard to put downstream economic strategies into practice. These include technology barriers, policy limits, and the need to balance protecting the environment with industrial growth. By bringing together insights from bibliometric analysis, the research suggests future steps for academics and decision-makers to overcome these difficulties and enhance downstream initiatives. The study also shows how economic policies can match sustainable development goals, presenting practical advice for industries that want to grow while managing their environmental effects.

3 Methodology

This study uses a bibliometric approach to review and interpret a large body of research on downstream economic activities and sustainable industrial growth. The method includes performance analysis, science mapping, and visualization tools used to track trends, impacts, and key contributions. Tools like Bibliometrix for R help find main research areas, new themes, and important publications [11]. The analysis looks at how downstream economic activities relate to sustainability, helping to identify strategic challenges and future research directions. By combining a wide range of bibliometric data, this method delivers a clear overview of present scientific discussions and trends in sustainable industrial practices.

3.1 Bibliometric Analysis Approach

Bibliometric analysis is a systematic approach to evaluating and interpreting a large amount of bibliometric data to understand the impact and trends within a specific research field. This method uses techniques such as performance analysis, science mapping, and visualization tools to assess the academic field. For instance, in the context of nanotechnology in diabetes mellitus, bibliometric tools such as Bibliometrix, VOSviewer, and CiteSpace are used to identify research focal points, including gene therapy and nanoparticles, which indicate directions for future research [12]. VOSviewer, as a tool to support bibliometric analysis, is useful for creating bibliometric maps in an easy-to-interpret way [13]. The bibliometric map from an extensive literature review can support a qualitative content analysis [14].

The relationship between periodontal disease and cardiovascular disease has also been explored through bibliometric analysis, using tools such as VOSviewer and CiteSpace to map the knowledge structure and identify emerging research areas such as the oral microbiome and inflammation [15]. Furthermore, the combination of big data and medical devices has been analyzed using bibliometric methods to uncover trends in AI, IoT, and genomic data analysis, stressing the role of smart healthcare and customized medicine [16].

Across the studies mentioned earlier, bibliometric analysis works as an effective means of synthesizing large volumes of research data, identifying key trends, and delivering important insights on future research directions, improving understanding and development across several scientific fields. Thus, we used similar tools to make a general review of the downstream economic activities related to its support for developing sustainable industrial growth.

3.2 Data Sources and Collection

Data sources were selected so as to ensure a focused examination of scientific contributions in the downstream economy and their effects on environmentally sustainable industrial growth. In general, we follow the article searching strategy made by [17] since it offered an efficient and simple way, with a larger data set, which was included in order to capture general insights. The primary data source is the Scopus database, chosen because of its extensive coverage of peer-reviewed academic publications across several disciplines, particularly energy, environment, and economics. The Scopus platform was selected due to its complete archive of high-quality journals and conference proceedings relevant to the scope of this study.

Data collection is done using a keyword-based search strategy, focusing on particular terms such as "economy" and "downstream," within fields of study such as “energy, “environment”, and “economics” (SUBJAREA: "ENER," "ENVI," "ECON"). The collected data is used as the starting point for analyzing trends, challenges, and future directions in the downstream economy and sustainable industry growth. In total, 19,883 documents were collected from 2,144 sources, including journals and books, adding to a continuously expanding body of literature, with an annual growth rate of 2.65%. The average age of the documents is 5.53 years, showing a balance between historical and contemporary research.

3.3 Tools and Techniques for Bibliometric Mapping

Bibliometric mapping is very useful for analyzing and visualizing the structure and dynamics in various fields of research. Several tools and techniques are used to carry it out, as have been widely employed in previous studies. Commonly used software tools include VOSviewer, CiteSpace, and the Bibliometrix package in R [11], which support the analysis of large data collections by providing functions for co-occurrence analysis of keywords, co-citation, and co-authorship [15], [18], [19], [20], [21]. For example, in studies on immune thrombocytopenia (ITP), these tools have been used to identify clusters related to diagnosis, pathophysiology, and treatment, emphasizing trends such as second-line therapies and novel treatments [18]. Similarly, in fields that might be considered quite different from the focus of this article, such as multiple sclerosis (MS), bibliometric analysis helps categorize publications into emerging, traditional, and cross-disciplinary disease-modifying therapies, with a focus on topics such as COVID-19 vaccination security and therapeutic inertia [15].

Indeed, similarly, even in fields related to the preservation of heritage buildings, bibliometric analysis is very powerful to show publication trends and joint effort networks, giving information on the evolution of research in this area [22]. Studies on the relationship between International Financial Reporting Standards (IFRS) and earnings management use performance analysis and science mapping to uncover key themes and emerging trends, as well as underscore areas for future research [19].

Furthermore, scientometric analysis of bone-cutting tools employs keyword co-occurrence and co-citation analysis to map the research landscape, identifying major trends such as surgical correctness and material innovation [23]. Collectively, studies from these varied fields demonstrate the versatility of bibliometric mapping tools and techniques in discovering research trends, collaboration networks, and possible areas for prospective exploration across several scientific domains.

3.4 Inclusion and Exclusion Criteria

Following the bibliometric analysis steps using VOSviewer from [24], articles were selected based on a series of inclusion and exclusion criteria to ensure a focused exploration of the downstream economy and its relationship with sustainable industrial growth. We applied inclusion criteria as follows: 1) only English-language articles were included to eliminate language bias, 2) sustainability-related keywords such as ‘Downstream,’ ‘Climate Change,’ and ‘Sustainable Development’. The latter criterion is to ensure that the articles addressed industrial and green sustainability, and 3) peer-reviewed articles, book chapters, conference papers, and reviews (DOCTYPE: "bk," "ch," "cp," "re," "ar"). Thus, articles that failed to meet these criteria were filtered out. This includes works published in languages other than English and studies outside the selected field of study.

We then applied exclusion criteria, such as publications that were not yet in the final stage of publication (PUBSTAGE: "final"). By applying this filter, this study assures that the dataset remains controllable and highly relevant, with a particular focus on the intersection between downstream economics and environmental industrial growth.

In total, 19,816 documents were included for further analysis. The majority of these documents were articles (15,629), followed by reviews (2,656), conference papers (919), and book chapters (612). The diversity of publication types indicates a strong engagement with both the theoretical and applied aspects of the field, stimulating a collection of understandings and methods.

4 Analysis

4.1 Thematic Map

This thematic map offers a deeper insight into the current research landscape in the fields of sustainable and environmental science, presenting the maturity and interconnections of various research themes. In particular, the core themes of 'sustainability,' 'sustainable development,' and 'optimization' serve as fundamental pillars underpinning much of the scholarly discussion. However, their position in the lower-right quadrant indicates significant opportunities for more theoretical and practical developments, as illustrated in Figure 1.

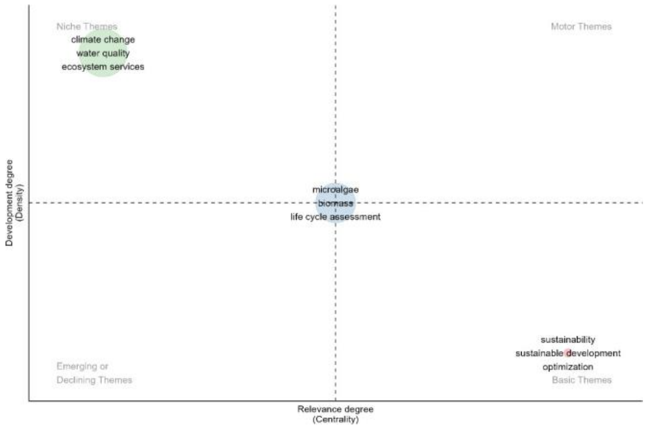

Fig. 1: Thematic Map
Source: created by the authors

Fig. 1: maps the research category themes based on relevance (centrality) and development (density). Climate change and water quality are specialized themes, while sustainability and optimization are fundamental. Topics such as ‘microalgae’ and ‘biomass’ appear in the middle, indicating a balance between development and relevance. Furthermore, this also shows that these topics are evolving and continue to be a trend in the field of research. Unlike 'climate change', 'water quality', and 'ecosystem services', which appear to have already developed and are also very specific, but have not yet widely become core themes in research fields

The central position of 'microalgae,' 'biomass,' and 'life cycle assessment' as highly interrelated themes indicates that these topics have become key components of sustainability research, notably in the context of renewable energy and circular economy models.

Thus, the map highlights a developing research landscape where emerging technologies and methods are increasingly integrated into the wider sustainable development agenda, indicating the demand for strategic investment in both specialized and fundamental areas to promote further innovation and tangible deployment.

4.2 Thematic Evolution

From a bibliometric perspective, the thematic change depicted in Figure 2 is consistent with the research agenda on downstream economics and sustainable industrialized growth. In the period of 1972-2015, themes such as ‘innovation,’ ‘sustainability,’ ‘water quality,’ and ‘supply chain management’ highlighted fundamental concerns in pollution control, environmental protection, and resource management. These topics are critical to strategic planning in downstream economics, since industries have begun dealing with the financial consequences of environmental regulations and the obligation for sustainable methods to support prolonged growth. The emergence of "sustainability" as a dominant theme during this era reflects an early recognition of matching industrial processes through environmental management, an essential part of downstream value-added processes, whilst maintaining environmental balance.

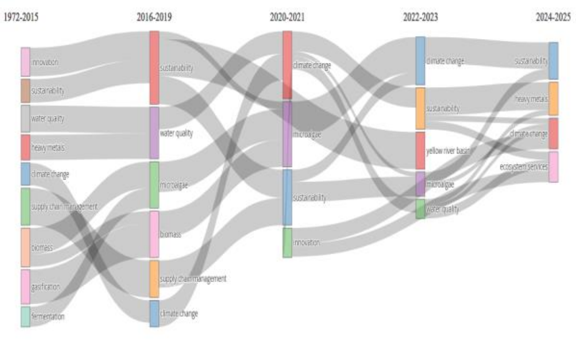

Fig. 2: Thematic change evolution
Source: created by the authors

The diagram in Figure 2 above also illustrates the evolution of research themes over wide time periods (1972–2025). Major themes such as climate change and sustainability have become increasingly prominent over time, indicating trends in research priorities. The flow of topics shows how earlier focuses on water quality and development have shifted to newer themes such as ecosystem services, heavy metals, and energy use, highlighting the changing nature of research trends.

In the more recent period (2016-2025), an increased focus on ‘climate change,’ ‘microalgae,’ ‘biomass,’ and ‘ecosystem services’ shows a deeper integration of sustainability into industrial practices. This trend indicates that industries are tackling environmental issues presented by climate change and exploring innovative pathways, including renewable energy and alternative inputs, to promote environmentally sustainable industrial growth. The emphasis on specific regional studies, such as the "Yellow River Basin," highlights strategic challenges in adapting eco-conscious practices to local contexts, particularly in resource management.

As research develops into 2024-2025, the inclusion of ‘ecosystem services’ signals a pathway for industries to align downstream economic outcomes with ecosystem restoration, further boosting sustainable industrialization goals that promote both economic growth and environmental robustness.

4.3 Factorial Analysis

The factorial analysis chart in Figure 3 illustrates the main thematic clusters and their relationships in research on sustainability, environmental management, and industrial growth. The red cluster, located at the center, highlights key themes such as ‘climate change,’ ‘sustainability,’ ‘urbanization,’ and ‘supply chain management,’ showing its central role in discussions about sustainable development and industrial practices. These themes appear to be closely interconnected, demonstrating high relevance in the transformation of strategic industries, particularly concerning environmental issues such as climate change and natural resource management. Meanwhile, the proximity between ‘conservation’ and ‘vulnerability’ indicates a growing interest in how industries can incorporate endurance and change strategies into their long-term strategies to reduce climate risks.

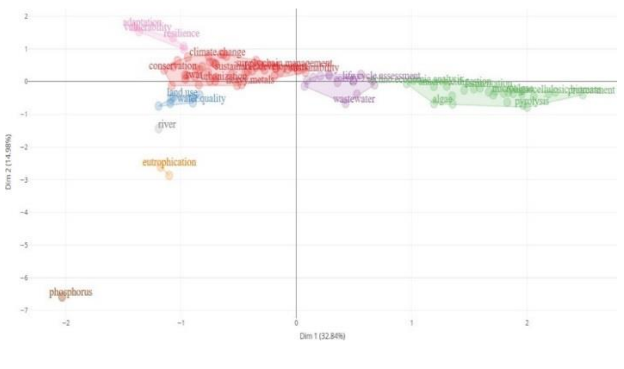

Fig. 3: Topics relationship based on factorial analysis
Source: created by the authors

On the periphery, other groups discussed more specialized themes. The green group, which included terms such as 'biomass,' 'pyrolysis,' and 'microalgae,' focused on technological innovations in bioenergy and renewable resources, representing a vital pathway for environmentally sustainable industrial growth. The separation of this group from the main topics shows its specific role in industrial applications, particularly in supporting renewable energy solutions.

The orange group, featuring notions like 'eutrophication' and 'phosphorus,' highlighted local environmental issues and their relevance to industrial impacts, particularly in water management. These peripheral topics underline the relevance of handling particular environmental consequences, while the main themes indicate broader, integrated discussions on sustainability and industrial transformation.

4.4 Collaboration Network

The collaboration network diagram, as shown in Figure 4, shows the dynamics of international research collaboration in the context of downstream economic growth and environmentally sustainable industrial development. China and the United States emerge as dominant players and shape the main collaboration networks, as indicated by the network positions centered on these two countries.

The strong relationship between China and the US reflects the importance of these two countries in driving global research, particularly in industrial sustainability. Their collaborative relationship demonstrates a common commitment to advancing downstream economic growth using technological innovation and eco-friendly practices, meeting global problems such as climate change and resource management.

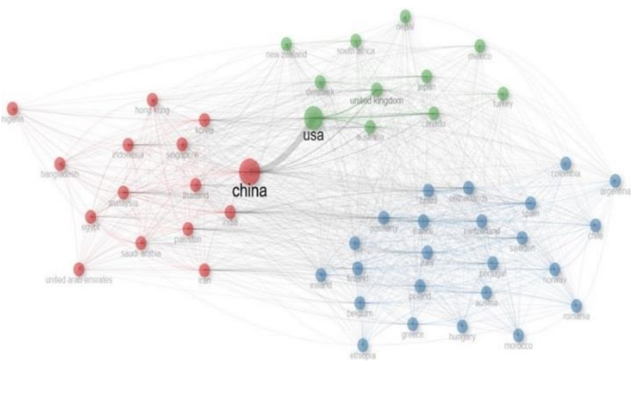

Fig. 4: Collaboration network
Source: created by the authors

This network also shows the existence of regional clusters, where the red cluster involves countries like India, Malaysia, and Iran, and the blue cluster encompasses European countries such as Germany, France, and Spain. These clusters indicate regional research collaborations focused on local issues in sustainable industry growth. For instance, Asian countries may concentrate on renewable energy and resource efficiency, while European countries may focus on regulatory frameworks as well as the circular economy. However, the diagram also points out the challenges in joining these regional clusters into a better, cohesive global research effort. Future pathways in the downstream economy will benefit from strengthened cooperation between these clusters, making certain that innovations in one region are shared and amplified globally to enable sustainable industrial growth.

5 Discussion

5.1 Strategic Challenges in Downstream Economics

Strategic challenges in the downstream economy, notably in sectors such as healthcare, manufacturing, and energy, include complicated interactions between organizational, financial, and operational factors. In the healthcare sector, strategic purchasing is important for universal health coverage, requiring clear policy design, effective organizational networks, and community participation to manage various streams of financing and service provider incentives [25]. In the energy sector, particularly in the liquefied natural gas (LNG) network, supply chain strategy (SCS) is important for economic results. Collaborative strategies are emphasized, but comprehensive implementation of all SCS is necessary to optimize monetary outcomes, indicating the necessity of strategic alignment across the supply chain [26].

In manufacturing, particularly in high-cost environments such as Sweden, companies meet challenges in sustaining competitiveness due to internal and external factors, including product characteristics, employee engagement, and supply chain collaboration. A prescriptive checklist of these problems can assist companies in dealing with high-cost landscapes [26]. Furthermore, in the context of specialization within a region such as Estonia or Wales, the shift towards location-based strategic innovation policies presents challenges in aligning local capabilities with broader economic needs, which requires a more comprehensive understanding of regional characteristics [27]. Finally, integrating sales strategies based on complementarity elasticity within supply chains involving complementary products is able to enhance competitiveness by improving sales and raising consumer utility, hence serving both the company and consumers [28].

These contexts point out the varied nature of strategic challenges in the downstream economy, which require a holistic approach that integrates policy design, supply chain management, regional innovation, and market strategies to properly address them and leverage them for economic expansion and sustainability.

5.2 Interplay between downstream economics and sustainable growth

The interaction between the downstream economy and environmentally sustainable growth is complex, including factors such as urbanization, financial development, and globalization, all of which have important consequences for environmental protection. Economic growth, which is often influenced by urbanization and the financial sector, tends to increase carbon dioxide (CO_2) emissions as well as ecological problems, as seen in the economic development in Gulf Cooperation Council (GCC) countries [29], [30], [31]. However, the impact of environmental degradation may be short-term, in accordance with the Environmental Kuznets Curve (EKC) theory, which states that economic growth initially causes environmental impacts, but ultimately economic prosperity will lead to an improved environment. This theory is backed in several developing countries, including China, where preliminary stages of economic growth increase the ecological footprint yet eventually contribute to environmental quality as the economy matures [32], [33].

Meanwhile, in Nigeria, although economic growth initially harms the environment, in the long term it ultimately improves environmental quality, indicating the potential for durable growth if managed properly [34]. Financial globalization also has an important role, as it can promote ecological sustainability by decreasing the ecological footprint, as observed in West Asian and Middle Eastern countries [35]. Employing renewable energy consumption is an additional essential element that can reduce CO_2 emissions, illustrating the significance of transitioning to clean energy sources to achieve environmentally sustainable development [29], [30], [31]. Therefore, the interaction between the downstream economy and environmentally sustainable growth requires an equitable approach that integrates economic, social, and environmental dimensions, making sure that economic activities are aligned with sustainability objectives. So that the authorities must design appropriate strategies to promote renewable energy, increase efficiency, and strengthen financial globalization in order to achieve sustainable development while reducing negative impacts on the environment [29], [30], [31], [32], [33], [34], [35].

5.3 Policy Implications for Industry and Economy

According to the specified context, the policy consequences for industry and the economy highlight the detailed role of industrial policies, competition, regulation, and disaster risk management. Sectoral policies that are specifically tailored for certain industries will more effectively increase productivity and drive growth, encouraging companies to innovate vertically rather than merely engaging in differentiation just to avoid competition [36]. Business support policies, such as investment subsidies, can greatly increase employment and reduce unemployment, particularly in small enterprises, without displacing jobs between eligible and ineligible regions. However, these policies do not always enhance Total Factor Productivity (TFP), indicating the requirement for attentive design to ensure wider economic benefits [37].

Integrating industrial ecology into management and policy studies shows that environmentally sustainable industrial systems can be achieved by connecting natural sciences and engineering with planned management, advancing a new sustainability mindset [38]. Regulations, although necessary, can adversely affect economic growth if they control prices and business entry in competitive markets. Therefore, developing countries should improve their regulatory evaluation capabilities to weigh economic impacts with social benefits [39].

Furthermore, the economic and policy consequences of disasters underline the significance of preparedness and impact mitigation. Policymakers should consider the costs of reducing the probability or impact of such events, as well as the prospective economic disturbances they may cause [40]. This insight provides us with the understanding that industrial policies and budget allocations must be carefully designed to promote competition, sustainability, and resilience, while simultaneously meeting the specific needs and varying capacities of each region and sector.

5.4 Future Pathways for Research and Industry Practices

Future research directions on the downstream economy and sustainable growth indicate the need for deeper integration between regional capabilities and the global sustainability framework. As evidenced by the substantial contributions from Chinese universities, such as Beijing Normal University and Tsinghua University, which publish more than 755 and over 600 articles annually, the focus is shifting towards region-specific solutions concerning sustainability issues and challenges (Figure 5). This reflects the strategic challenge of matching local research priorities with global industrial sustainability efforts, especially in rapidly developing regions.

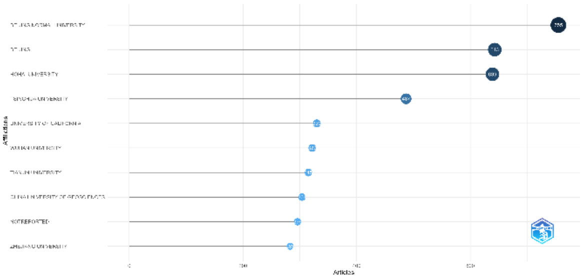

Fig. 5: Academic affiliation productivity
Source: created by the authors

Data on author productivity over time additionally emphasizes that prolific researchers, such as Wang Y and Zhang Y, have made important contributions to this field, with more than 300 articles, indicating increasing academic attention to economically viable and environmentally sustainable industrial strategies (Figure 6). However, the trend towards high output and declining citation rates in recent years suggests the need for more impactful, innovative research that extends the frontiers of existing industrial practices, particularly in renewable energy, the circular economy, and ecosystem restoration. Subsequent research ought to focus on interdisciplinary approaches that address technological and policy gaps in this field.

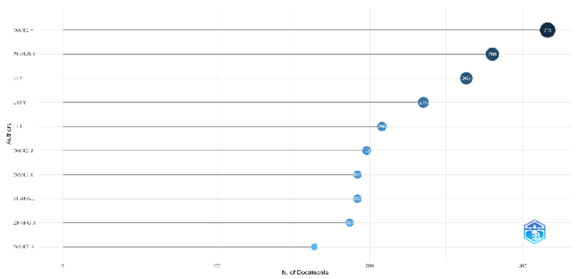

Fig. 6: Authors' productivity
Source: created by the authors

Co-occurrence analysis showcases critical emerging topics such as "biomass," "microalgae," and "life cycle assessment," which are becoming central in the discussion of industrial sustainability (Figure 7). These concepts underline the turn towards bioenergy and renewable resources as key pathways for lowering the ecological burden of industrial activities.

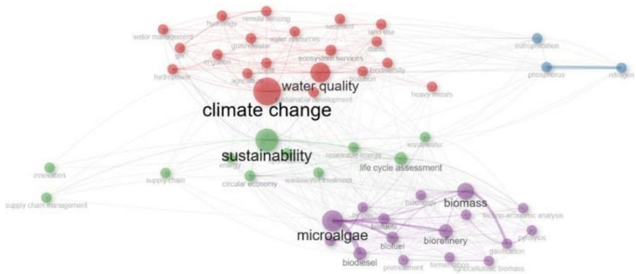

Fig. 7: Co-occurrence network of key research topics
Source: created by the authors

However, as research develops, integrating the "circular economy" model with more comprehensive "supply chain management" strategies will be vital to scaling this innovation across industries. A strong global collaborative network, particularly between China and the US, stresses the significance of global cooperation in furthering this research pathway (Figure 4). Nevertheless, the challenge remains to ensure that zones with lower output, such as Africa and South America, are better integrated into international initiatives to share knowledge and encourage fair and durable growth.

6 Conclusion

6.1 Key Findings

A bibliometric analysis from 1972 to 2025 highlights key findings on the downstream economy and environmentally sustainable industrial growth. Firstly, the growth of research output, particularly after 2010, demonstrates a considerable increase in global attention in the direction of sustainable industrial practices, with China leading the field in both solo and collaborative research efforts. Thematic change reveals a shift that moves away from traditional environmental management topics, such as 'water quality' and 'supply chain management,' to more specialized and influential areas like 'biomass' and 'ecosystem services' (Figure 2).

However, citation trends show potential saturation in this field, with the average citations per article declining after 2019, indicating the need for increasingly targeted and high-impact research in specialized sustainability and resource efficiency areas, as illustrated in Figure 8.

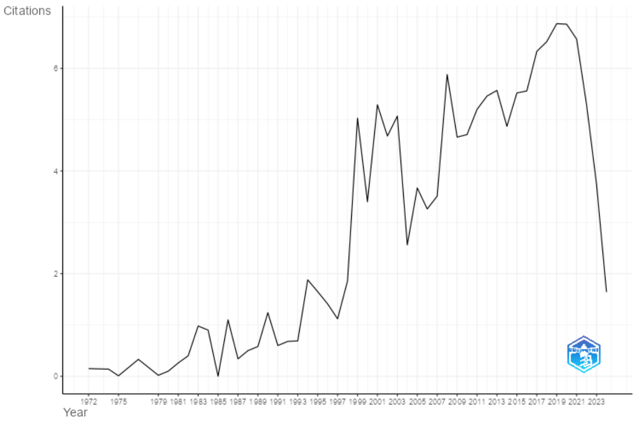

Fig. 8: Average citations per article related to downstream economics and sustainable industrial growth
Source: created by the authors

Figure 8 illustrates the trend of average citations per article (MeanTCperArt) and average citations per year (MeanTCperYear) over time, reflecting different patterns in the academic impact of research on downstream economics and environmentally sustainable industrial growth. From 1972 to 1992, the average citations per article were relatively low, fluctuating between 0.5 and 1.7 citations, indicating that this field of research was still in its formative stage.

However, for certain articles, some of those published in 1983 and 1986, received much higher average citations per year, reaching 41 and 43 citations, respectively, suggesting the emergence of meaningful studies. This high citation rate indicates that specific fundamental works started to attract attention and were recognized as valuable contributions in the field.

6.2 Implications for Policymakers and Industry Stakeholders

To policymakers and industry stakeholders, the results show that although research on the downstream economy is increasingly developing, its tactical application remains uneven. Currently, China and the U.S. appear to dominate in terms of research output, so these two countries seem likely to become the policymakers for industries related to sustainability initiatives in the future.

Nevertheless, the framework of worldwide collaboration stresses the significance of inclusive international partnerships. Policymakers should promote interdisciplinary research and provide incentives for innovation in bioenergy and the circular economy, aligning industrial productivity with green management.

For industry, notably in sectors such as manufacturing and energy, increased research on technologies such as 'biomass' and 'microalgae' shows encouraging paths for diminishing environmentally harmful effects while upholding economic sustainability.

6.3 Implications for Further Research

Future research needs to focus on formulating scalable technologies that incorporate renewable energy supplies into industrial processes, as evidenced by the growing interest in bioenergy and circular economy models. Furthermore, there is an urgent need to bridge the gap between high-output and high-impact research, notably in regions with lower average citation rates, such as China and India.

Exploration of the potential for international collaboration to address local environmental issues, focusing on an interdisciplinary approach that integrates technological innovation, policy design, and economic efficiency, becomes crucial. Finally, as the discussion about emerging areas such as 'ecosystem services' and 'life cycle assessment' also becomes increasingly central, future studies must further explore the durable sustainability impacts of industrial practices and supply usable insights to stakeholders in both academia and industry.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the author(s) used Deepseek in order to increase the readability and efficiency of sentences of the article. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Conceptualisation, Bahlil Lahadalia (BL) and Athor Subroto (AS).; methodology, AS and BL.; writing—original draft preparation, BL.; writing—review and editing, AS, BL. All authors have read and agreed to the published version of the manuscript.
Source of Funding

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study
Conflicts of Interests

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.