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Open innovation practices and environmental sustainability: a systematic literature review

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ABSTRACT - The concept of sustainability is increasingly recognized as a major imperative in the face of environmental challenges. Although sustainable practices meet government standards, their implementation is hampered by a number of obstacles, such as a lack of knowledge or sustainable technologies. In this context, innovation plays a central role, in particular open innovation, which is based on sharing ideas, resources and knowledge with the various stakeholders, thus facilitating collaboration around a

sustainable project. As the link between open innovation practices and environmental sustainability is little explored, our aim is to contribute to the understanding of open innovation practices in the resolution of environmental challenges associated with the implementation of sustainable practices. To this end, we conducted a systematic literature review comprising 71 scientific articles published between 2011 and December 2023. This research was carried out in two parts: a bibliometric part and a qualitative analysis.

Keywords : open innovation, environmental sustainability, collaboration, sustainable innovation

1. Introduction

Environmental sustainability has emerged as a critical imperative in addressing today's pressing environmental challenges. The 2030 Agenda, endorsed by the United Nations since 2015, outlines the 17 Sustainable Development Goals (SDGs) that aim to create a sustainable world by 2030 through the adoption of sustainable practices (Bigliardi & Filippelli, 2022; Bogers et al., 2020; Kanter et al., 2018). However, the implementation of these practices faces numerous challenges (Bigliardi & Filippelli, 2022), which can be overcome through

innovation (Archambault & Nakhla, 2015), which relies on the sharing of ideas, resources, and knowledge to stimulate innovation and accelerate product development (Chesbrough & Bogers, 2014).

In the literature, various terms such as ecoinnovation (Nuryakin et al., 2022), green innovation (Meidute-Kavaliauskiene et al., 2021), or sustainable oriented innovation (Ponta et al., 2022) have emerged, each highlighting a nuanced interaction between sustainability and open innovation. So, Bogers et al. (2020) propose the concept of sustainable open innovation as a new research field that combines the two concepts of open innovation and sustainability.

While several studies have examined the role of open innovation in supporting the transition to a sustainable enterprise (Arcese et al., 2015; Bigliardi & Filippelli, 2022; Hung & Chou, 2013; Meidute-Kavaliauskiene et al., 2021; Payán-Sánchez et al., 2021), the relationship between open innovation and sustainability is not yet clearly defined. To bridge this gap, this study aims to conduct a systematic literature review to explore the open innovation practices that effectively address the challenges of implementing environmental sustainability. The research question guiding this study is: "What are the open innovation practices that contribute to addressing the challenges encountered in implementing environmental sustainability?"

By identifying the key open innovation practices that contribute to addressing environmental challenges, this research will enhance our theoretical understanding of the intersection between open innovation and sustainability. It will provide insights into the specific approaches and strategies that organizations can adopt to foster collaboration and innovation for sustainable development. From a managerial perspective, the findings will offer practical insights for managers and decision-makers in organizations seeking to integrate sustainability into their operations. This will enable them to navigate the challenges associated with sustainable practices more effectively and contribute to the achievement of the Sustainable Development Goals outlined in the 2030 Agenda.

2. Theoretical background

a) Environnemental sustainability

Environmental sustainability has emerged as a major imperative in the field of management today, due to the urgent challenges posed by climate change, biodiversity loss, and ecosystem degradation. This concept has become a central pivot in both academic debates and commercial strategies over the past two decades (Dyllick & Hockerts, 2002; Scoones, 2010). It constitutes a vital lever of action for governments, businesses, and society as a whole, in the face of global issues such as climate change, energy management, waste reduction, environmental preservation, and natural resource depletion. Environmental sustainability has become a strategic imperative for businesses concerned about their ecological footprint and their contribution to addressing global environmental challenges (Klewitz & Hansen, 2014; Schaltegger et al., 2016). Companies adopt various strategic approaches to integrate environmental sustainability into their operations (Cantino et al., 2019). These approaches include reducing the environmental footprint of operations, innovation in products and processes (Bocken et al., 2015), regulatory compliance, and transparent communication on environmental performance and stakeholder engagement (Haffar & Searcy, 2018). Although obtaining labels such as ISO 14001 or ISO 26000 allows companies to enhance their brand image and strengthen their competitive advantage (Arcese et al., 2015), the implementation of sustainable practices faces various challenges such as lack of resources and knowledge, as well as difficult market access in the absence of sustainability standards compliance.

In this context, innovation, as a driver of change, plays a crucial role in promoting sustainable development (Rauter et al., 2017), and more specifically sustainable innovation, which aims primarily to develop solutions for sustainability through the creation of more sustainable products, services, or technologies (Bigliardi & Filippelli, 2022). This type of innovation relies on companies' ability to integrate various stakeholders such as customers, suppliers, and research institutes (Rauter et al., 2017). Furthermore, despite the growing interest of companies in addressing SDGs' challenges, public funds allocated to these initiatives are generally insufficient. This underscores the crucial importance of public-private partnerships and collaborations to address these challenges (Bogers & West, 2012). Therefore, the intersection of open innovation and environmental sustainability is garnering increasing interest, reflecting the recognition of their combined potential to address contemporary environmental challenges.

b) Sustainable open innovation

The emergence of sustainability goals has given rise to various innovation: eco-innovation, sustainability-oriented innovation, green innovation, and sustainable open innovation. The objective of each of these innovations is the same: to innovate sustainably by acting in favor of the environment. However, each terminology pertains to a specific type of innovation (Table 1). While green innovation solely focuses on the environment (Meidute-Kavaliauskiene et al., 2021), ecoinnovation (Nuryakin et al., 2022; Sanni & Verdolini, 2022) and sustainable-oriented innovation (Ponta et al., 2022) aim to create economic or economic and social value in addition to their environmental impact, respectively. Open sustainable innovation relies on the sharing or exchange of information, knowledge, technologies, or resources among project stakeholders, with the aim of innovating for the environment (Loilier & Tellier, 2011).

Typology of innovation	Definition	Differences between typologies of innovation
Green innovation	Innovation aimed at ecological sustainability: reducing greenhouse gas emissions, waste, pollutants, or preserving natural resources (Tjahjadi et al., 2020)	Primarily ecological objective
Ecoinnovation	Innovation aiming to reconcile environmental sustainability with economic value creation (Nuryakin et al., 2022; Sanni & Verdolini, 2022)	Ecological and economic objective to strike a balance between environmental preservation and financial profitability
Sustainable-oriented innovation	Innovation aiming to integrate environmentally sustainable considerations while creating economic and social value (Ponta et al., 2022)	Ecological, economic, and social objectives to create sustainable and profitable innovation
Sustainable open innovation	Open innovation (involving sharing with stakeholders) acting for the environment (Bigliardi & Filippelli, 2022)	Sharing of information, techniques, or resources (collaboration) with stakeholders

Table 1 : Summary of technical differences in ecological innovation

Several studies have explored the synergies between open innovation and environmental sustainability. For instance, Arcese et al. (2015) examined how companies can utilize open innovation platforms to develop sustainable solutions in collaboration with external stakeholders. Similarly, Meidute-Kavaliauskiene et al. (2021) investigated the impact of open innovation on companies' environmental performance. Increasingly, industries have recognized the value of embracing open innovation, particularly for its ability to minimize expenses by leveraging others' ideas at lower costs while expediting the process (Weil et al., 2010).

The introduction of the term « sustainable open innovation » by Bogers in 2020 has directly linked open innovation and sustainability (Kimpimäki et al., 2022; Lippolis et al., 2023). In Bogers et al. (2020) case study, the « Green Fiber Bottle » is an innovation involving multiple stakeholders to innovate sustainably and respect the environment. Open innovation can be expressed through various collaboration approaches: « outside-in », « inside-out » or « coupled-process » (Chesbrough, 2012). Each of these approaches allows for different open innovation practices (Table 2), such as co-design, knowledge acquisition, or spin-offs (Pillon & Louis, 2023).

Open Innovation Approach		Definition
Inside-out	Licensing out	Granting permission to use the company's intellectual property via licenses or patents
	Spin off	Establishing a new organization to capitalize on and commercialize disruptive technologies autonomously
Outside-in	Co-creation	Collaborating with various stakeholders to design a product
	Crowdsourcing	Delegating activities to anonymous actors through a platform
	Licensing in	Acquiring usage rights to external intellectual property for leveraging external knowledge
	Know-how Acquisition	Obtaining research and development services offered by external entities
	Networking	Leveraging a collaborative network, developing relationships and partnerships
	Capital-venture	Investing in a promising venture through venture capital
Coupled process	Collaborative R&D	Developing external R&D through multiple collaborators
	Research Consortium	Collaborating with different research actors
	Strategic Alliance (M&A)	Acquiring and merging a company with strategic values
	Open source	Providing a product for free, which can be modified and redistributed freely

Table 2 : The different practices of open innovation and their definitions (Pillon,2021).

Many researchers have begun to explore this concept of "sustainable open innovation." Four main research themes have been identified: SOI linked to innovation performance, the impact of technological capability on SOI development, university collaboration for SOI, and business models (Bigliardi & Filippelli, 2022). Although existing literature highlights the potential of open innovation to promote environmental sustainability, some gaps still exist (Bigliardi & Filippelli, 2022; Payán-Sánchez et al., 2021).

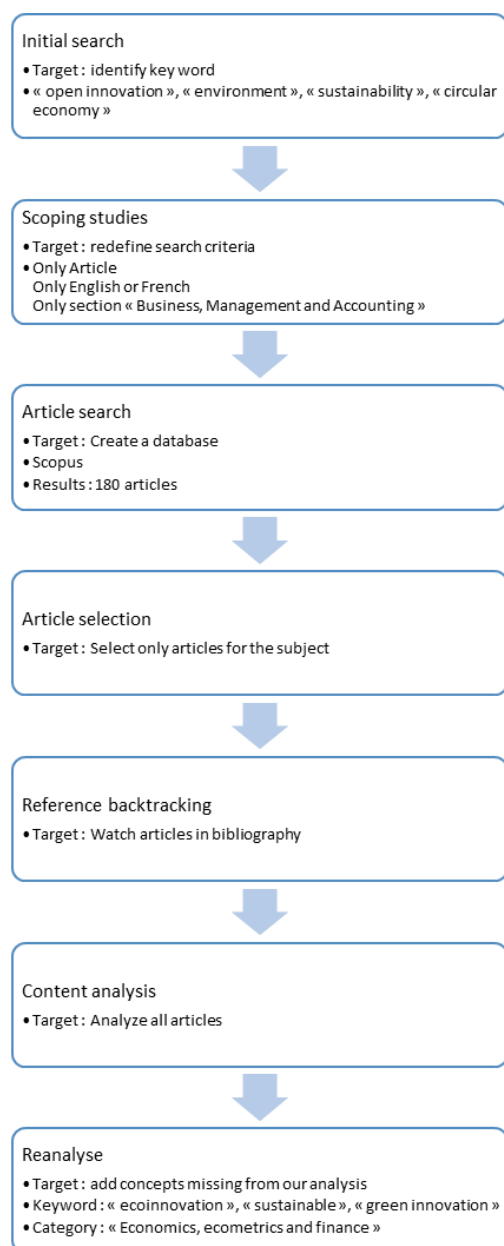
3. Methodology

Our research aims to identify a comprehensive range of open innovation practices that effectively address the challenges encountered during the implementation of sustainable development.

To ensure the thoroughness and reliability of our investigation, we have opted for a systematic literature review methodology, following the approach proposed by Biggi & Giuliani (2021). This methodological selection is grounded in a thorough comparison of prior studies by Scaringella, L., & Radziwon (2017), Tranfield et al. (2003) and Biggi & Giuliani (2021). By employing the methodology outlined by Biggi & Giuliani (2021) we can meticulously examine all relevant literature, thus minimizing the risk of overlooking pertinent insights, while remaining mindful of potential biases that may arise despite our concerted efforts to mitigate them.

The analysis was conducted through several steps, as illustrated in . This process aims to perform a bibliometric analysis of the literature and then analyze the content of the selected articles according to the outlined process.

The method used consists of 7 steps (see):



• Initial search

In this phase, the objective is to define relevant keywords. For this study, we selected the terms "open innovation," "environment," "sustainability," and "circular economy." These keywords were chosen based on the relevance of the topic.

• Scoping studies

This involves defining the search criteria: we chose to limit our selection to articles in the "Business, Management and accounting" category. The chosen languages are French and English, as they are the most commonly used in the field of management.

• Articles search

We used the Scopus database for these searches. This choice was based on previous works such as those of Scaringella, L., & Radziwon (2017). This initial search gave us access to 180 articles.

• Article selection

We read each abstract to understand the subject and concept studied in each article. Only articles relevant to our research field were retained, while others were excluded.

• Reference backtracking

This step involves retrieving all articles that correspond to our research by taking the bibliography of each selected article to identify other relevant sources, reaching a saturation point.

Figure 1 : Methodology

- Content analysis

Each selected article is read to conduct a content analysis and understand the concepts and arguments related to open innovation and sustainable development.

- Re-analysis

While reading the literature, we took into account other concepts and keywords such as "ecoinnovation," "sustainable," or "green innovation." We enriched our search with these words, as well as with the "Economics, econometrics and finance" category.

We thus retained 78 articles for analysis.

3. Data analysis

a) Bibliometric analysis

This systematic literature review comprises 71 articles from 39 different journals.

These articles are mainly from the journals: *Journal of Open Innovation: Technology, Market, and Complexity* (15), *Journal of Cleaner Production* (8), *Business Strategy and the Environment* (4) and *Journal of Business Research* (4). The numbers in parentheses correspond to the number of articles published in these journals.

Regarding the analysis by year (Figure 2), since 2019, the writing of articles concerning the link between open innovation and the environment has significantly increased. This can be explained by the interest in innovation for the environment, particularly with the emergence of various typologies. These results are consistent with those of Chistov et al. (2021) and Bigliardi & Filippelli (2022).

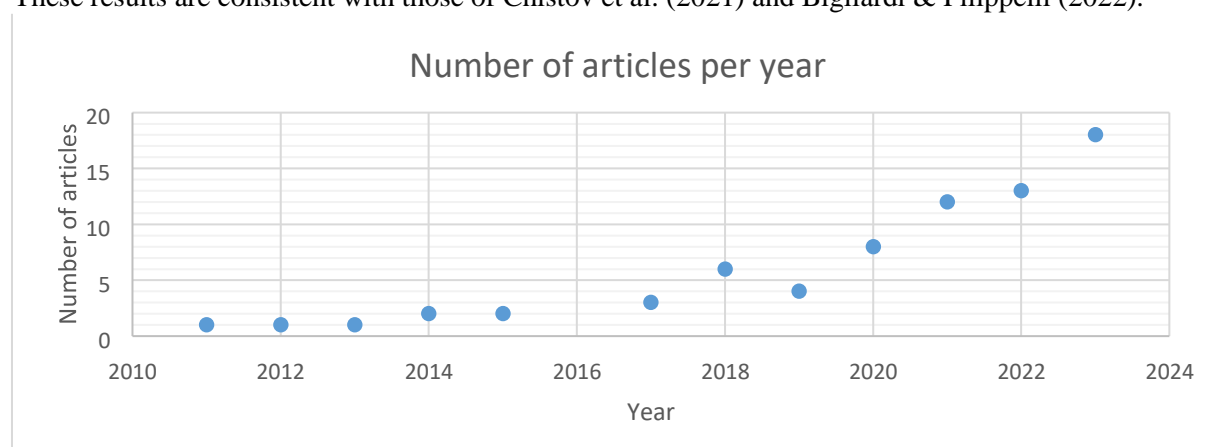


Figure 2 : Number of articles per year

To analyze the frequency of the most common keywords, the VOS viewer software allowed us to create a mapping according to clusters (Figure 3). This mapping highlights the main subject of the articles, which is, as expected, open innovation. However, other types of innovation for environmental sustainability are also represented, such as green innovation or eco-innovation. The mapping emphasizes three distinct clusters. The first cluster, represented in red, associates green innovation with business strategies and performance. The second cluster, in blue, focuses on environmental impact, while the third cluster, in green, also integrates social and economic dimensions. Through this figure, we can observe that the importance of balance between the three pillars: social, economic, and environmental, is also reflected in the literature.

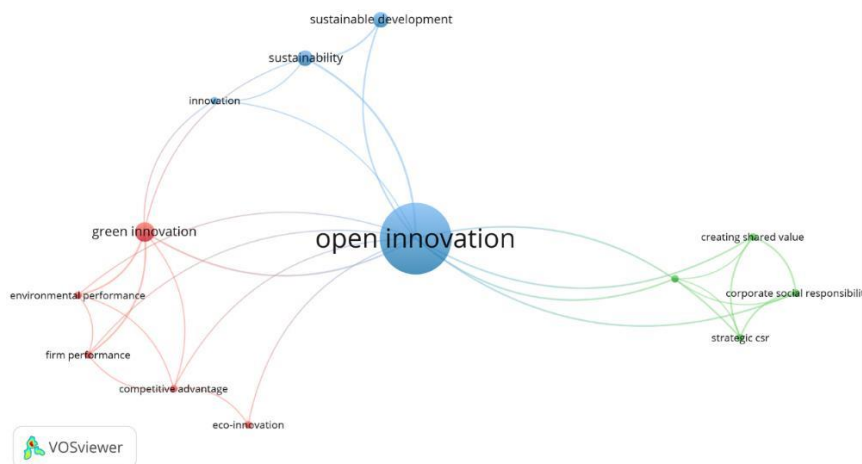


Figure 3 : Keyword cluster – Source VOS Viewer

b) Analysis of the results

Enterprises increasingly face environmental challenges, a topic explored in the literature on sustainable practices adoption. Among these challenges, the lack of human, financial resources, and time constraints emerge as primary obstacles (Bruna, 2019; Hattabou & Louitri, 2011). Integrating innovation into the corporate strategy represents another significant challenge (Berger-Douce, 2011).

By surmounting these challenges through innovative practices, they have the opportunity to enhance their brand image and maintain competitiveness (Arcese et al., 2015; Ghassim & Foss, 2021). Sustainable open innovation provides the opportunity to adopt innovative practices through collaboration among multiple stakeholders (Bigliardi & Filippelli, 2022; Greco et al., 2021).

The results of our analysis are summarized in Table 3.

Lack of human resources

With the increasing number and stringency of environmental standards, the primary challenge in adopting environmental practices is to obtain the necessary certifications and be able to produce sustainably.

Various approaches address this shortfall by enhancing knowledge acquisition:

- Licensing-in enables companies to proactively acquire technologies or knowledge to meet the requirements of environmental standards and obtain the necessary certifications (Hu et al., 2017; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)
- Strategic alliance and venture capital, offer the opportunity to integrate a company with innovative environmental solutions in order to acquire key environmental data (Arcese et al., 2015)
- Know-how acquisition enables research into environmental products to be outsourced, thus avoiding the need to comply with environmental standards (Hu et al., 2017)
- The network promotes exchange between different parties, enabling knowledge and resources to be acquired and shared, developing new partners and relationships (Arcese et al., 2015; Bogers et al., 2020; Greco et al., 2021; Jesus & Jugend, 2023; Kennedy et al., 2017; Long et al., 2020; Ponta et al., 2022)
- Licensing-out is the principle of granting one's intellectual property to another company. Here, like licensing-in, this innovation practice enables the sharing of information and technologies, such as knowledge in terms of environmental

sustainability (Arcese et al., 2015; Bogers et al., 2020; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)

- Co-design, involving stakeholders in the development process, promotes the creation of a product with everyone's specific knowledge. This makes it possible to design a product with the best manufacturing conditions: fewer carbon emissions, with less toxic and polluting raw materials (Arcese et al., 2015) or even to manufacture it in a cleaner production facility (Ponta et al., 2022). Co-design brings a sustainable approach to increasing the life-cycling of innovation and product, which reinforces its sustainability (Medina-Salgado et al., 2021).

Lack of financial resources

Lack of resources is also highlighted as an obstacle to the adoption of sustainable practices. Open innovation offers solutions to this problem by adopting practices such as:

- Co-design challenges or competitions to unlock additional funding or attract new investors (Greco et al., 2021)
- Strategic alliances and venture capital, also in this context, make it possible to integrate an environmental dimension into the parent company at lower cost, with the purchase of environmentally conscious companies (Arcese et al., 2015)
- Networking reduces time-to-market by leveraging partnerships (Greco et al., 2021)
- Crowdsourcing collects the opinions of anonymous users on a platform to develop and sell environmentally-friendly products, thus guaranteeing their attractiveness on the market (Allal-Chérif et al., 2023; Pattinson et al., 2023; Rauter et al., 2019; Robertsone & Lapina, 2023)
- Licensing-out can also bring in revenue by selling licenses or even patents to share knowledge (Arcese et al., 2015; Bogers et al., 2020; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)

Lack of ideas

At the same time, developing innovative ideas to meet environmental challenges is a major challenge. Open innovation encourages creativity and the generation of new ideas through participative approaches:

- Co-design enables the integration of stakeholders in the innovation process. Here, challenges or competitions are organized to stimulate innovation (Greco et al., 2021). Online platforms or living labs also enable new products to be created with full knowledge of application conditions (Kimpimäki et al., 2022).

Challenges	Open Innovation Approach	Environmental Actions	Source
Lack of Human Resources	Licensing-in	Proactive acquisition of crucial technologies or knowledge to meet environmental standards and obtain necessary certifications	(Hu et al., 2017; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)
	Strategic Alliance	Integration of innovative and environmentally conscious solutions from strategic partners	(Arcese et al., 2015)
	Acquisition of Know-How	Outsourcing research on environmental products, thereby overcoming barriers related to knowledge gaps	(Hu et al., 2017)
	Networking	Exchange among parties, sharing of knowledge and best practices, thereby enhancing companies' innovation capacity in environmental sustainability	(Arcese et al., 2015; Bogers et al., 2020; Greco et al., 2021; Jesus & Jugend, 2023; Kennedy et al., 2017; Long et al., 2020; Ponta et al., 2022)
	Licensing-out	Sharing of environmental knowledge and technologies, fostering open innovation and progress in sustainability	(Arcese et al., 2015; Bogers et al., 2020; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)
	Co-creation	Collaborative involvement of stakeholders, collaborative product design of eco-friendly products, considering environmental concerns from the design phase	(Arcese et al., 2015)
Lack of Financial Resources	Co-creation	Organizing challenges or contests to unlock additional funds or attract new investors interested in developing sustainable solutions	(Greco et al., 2021)
	Strategic Alliance and Capital-Venture	Cost-effective integration of environmental solutions into the parent company, thereby strengthening its ability to address environmental challenges	(Arcese et al., 2015)
	Networking	Reduction of time-to-market through effective partnerships, thereby accelerating the market entry of innovative environmental solutions	(Greco et al., 2021)
	Crowdsourcing	Collection of user feedback on online platforms, enabling the development and commercialization of environmentally friendly products, ensuring their market success	(Allal-Chérif et al., 2023; Pattinson et al., 2023; Rauter et al., 2019; Robertsone & Lapiņa, 2023)

	Licensing-out	Sale of licenses or patents related to environmental innovations, contributing to the dissemination of knowledge and progress in environmental sustainability	(Arcese et al., 2015; Bogers et al., 2020; Ponta et al., 2022; Saguy & Sirotinskaya, 2014)
Lack of Ideas	Co-creation	Organization of challenges or contests to stimulate innovation and creativity, and creation of new products with defined application conditions	(Greco et al., 2021)
	Online Platforms or Living Labs	Development of new products while understanding application conditions through the use of online platforms or co-creation labs	(Kimpimäki et al., 2022)

Table 3 : Open innovation approaches to environmental challenges

4. Discussion

The results obtained provide perspectives for discussion. Firstly, open innovation approaches seems not to be fully exploited in the development of sustainable practices. Specifically, strategies such as open-source or spin-off creation are not utilized. This observation could be attributed to the composition of the selected article sample, but it generally confirms the earlier conclusions of Arcese (2015). Moreover, we noted that no practices classified under the "coupled process" category have been exploited, suggesting potential areas for further exploration. In fact, practices in the coupled process category are often conflated with cocreation. In the study by Jesus & Jugend (2023), the use of the term co-creation falls under the coupled process category, while we identified it as outside-in. Conversely, co-creation is present in every row of the summary table. This approach thus aids businesses in addressing challenges related to adopting sustainable practices.

Also, the analysis reveals that open innovation practices have the potential to significantly contribute to addressing the challenges associated with implementing environmental sustainability. Through the sharing of ideas, resources, and knowledge with various stakeholders, organizations can foster collaboration and stimulate innovation for sustainable development. This finding aligns with previous research that highlights the positive impact of open innovation on organizational performance and competitiveness.

Furthermore, the review highlights the importance of adopting a sustainable open innovation approach. This approach emphasizes the integration of sustainability principles into the entire innovation process, recognizing the need for organizations to align their innovation efforts with environmental goals and societal impact considerations. The analysis also reveals the existence of various open innovation practices that can effectively support environmental sustainability, including collaborative platforms, crowdsourcing, co-creation, and partnerships with external stakeholders.

5. Conclusion and perspectives

In conclusion, this study provides valuable insights into the relationship between open innovation practices and environmental sustainability. Based on quantitative bibliometric techniques and a qualitative analysis of the literature, it identifies how current challenges can be met through a variety of open innovation practices. Currently, few companies have a clear understanding of open innovation practices that could help them overcome these environmental barriers and integrate sustainable practices. This research aims to address this gap by providing companies with valuable insights to target and tailor their open innovation approach based on the specific environmental needs they face.

Indeed, depending on the specific environmental challenges faced, different open innovation approaches may be more or less suitable. The environmental challenges taken into account are the lack of knowledge, the lack of resources and the development of ideas. Insufficient knowledge and resources can lead to various issues, such as non-compliance with environmental standards or facing penalties. To address this challenge, sharing knowledge through open innovation approaches such as licensing-in or licensing-out, strategic alliances, knowledge acquisition, networking, and co-creation can offer effective solutions. The lack of financial resources can be addressed in several ways: by integrating a new source of income, by selling more quickly and securely, or by integrating a new environmental dimension into the company at lower cost. Each of these challenges can be addressed with an open innovation approach. Licensing-out enables the integration of a new source of income. To sell more securely and quickly, crowdsourcing, co-creation, and networking address this issue. Strategic alliances allow the integration of an environmental dimension by acquiring a company.

Approaches such as co-creation or online platforms facilitate idea development, particularly through challenges or contests. Idea development enables a company to remain competitive while innovating sustainably and respecting the environment. According to Greco et al. (2021), challenges have enabled companies to establish a network and foster deeper reflection on sustainable innovation.

Theoretical implications of this research are manifold. Firstly, this study enhances our understanding of the intersection between open innovation and environmental sustainability. The results confirm that open innovation practices can have a positive impact on environmental sustainability by fostering collaboration and innovation for sustainable development. This supports existing theories on the role of open innovation in organizational performance and competitiveness. Furthermore, this research contributes to the emergence of the field of sustainable open innovation. By emphasizing the importance of integrating sustainability principles throughout the innovation process, this study underscores the need to rethink our approaches and theoretical frameworks to address environmental challenges. It thus opens up new avenues for future research in this emerging field.

Concerning managerial implications, our findings demonstrate that open innovation practices can help organizations promote environmental sustainability. Managers can utilize collaborative platforms, crowdsourcing, stakeholder co-creation, and strategic partnerships to encourage sustainable innovation. By adopting these practices, organizations enhance their ability to address environmental challenges and contribute to achieving the Sustainable Development Goals outlined in the 2030 Agenda.

However, it is important to acknowledge the limitations of this study. The findings are based on a systematic literature review from Scopus database. Even if we conducted a bibliography analysis of each article until saturation was reached, further research could be conducted using another database, such as Web of Science. Additionally, further empirical research is needed to validate and expand upon these findings. Moreover, the generalizability of the results may be limited to specific industries or contexts such as food and beverage (Arcese et al., 2015) and future studies should explore the applicability of open innovation practices in different settings (Gagné et al., 2022).

Future research could focus on small and medium-sized enterprises (SMEs) and their adoption of open innovation approaches related to sustainable development, as this area remains relatively underexplored (Berger-Douce, 2011; Gagné et al., 2022).

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