

Review

Sustainability and Open Innovation: Main Themes and Research Trajectories

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Abstract: Today, innovation and sustainability in their broadest sense, which includes people (social dimension), the planet (environmental dimension) and profits (economic dimension), are increasingly intertwined. Integrating the sustainability dimension into the innovation of products, services, processes, technologies, business and organizational models requires an effort on the part of the company as it demands a different set of knowledge and skills than those needed to innovate in a traditional way. As a result, companies, in order to integrate the dimension of sustainability in their innovation processes, have felt the need to exploit knowledge, skills and technologies external to the organization itself, promoting what is called the process of open innovation. Since this field of field is only recently being explored, we conducted a literature review through bibliometric analysis on a sample of 93 scientific articles published between 2011 and today, April 2022. To achieve the purpose of this review, both quantitative (co-occurrence analysis) and qualitative analysis have been conducted. Four different research themes have been identified: sustainable open innovation and innovation performance, the role of technological capability for sustainable open innovation, business model perspective and sustainable open innovation and university collaboration. As far as future research is concerned, a mainline has been identified concerning the study of sustainable open innovation in the agri-food industry.

Keywords: sustainable open innovation; bibliometric analysis; review; open innovation; sustainable innovation



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1. Introduction

Sustainability is becoming the reference for the new normal and the backbone of current innovation paths. Even within the company, the concept of sustainability is intrinsically linked to that of digital transformation and increasingly permeates all areas of business, from governance to operations. Sustainability and innovation have often been considered opposing forces. In particular, in the past, the implementation of technological and industrial innovations has been considered one of the main causes of the depletion of natural resources. Today, however, innovation and sustainability in their broadest sense, which includes people (social dimension), the planet (environmental dimension) and profits (economic dimension), are increasingly intertwined. Since the link between sustainability and innovation began to gain considerable importance, starting in the early 2000s researchers and practitioners began to take an interest in the topic by placing significant emphasis on understanding how these two concepts could intersect in a virtuous way [1]. This has caused the emergence of a new form of innovation, termed sustainable innovation, which is defined [2] as the process in which considerations concerning the three dimensions of sustainability—environmental, social, and economic—are effectively integrated into business systems from the idea generation stage to the final commercialization stage. Integrating the sustainability dimension into the innovation of

products, services, processes, technologies, business and organizational models requires an effort on the part of the company as it demands a different set of knowledge and skills than those needed to innovate in a traditional way [3]. For this reason, access to different sources of knowledge and resources acquires considerable importance compared to the case of traditional innovation, in which knowledge and resources possessed internally by the company turn out to be largely sufficient. As a result, in order to integrate the dimension of sustainability in their innovation processes, companies have felt the need to exploit the knowledge, skills and technologies external to the organization itself, promoting what is called the process of open innovation [4]. Since 2003, studies related to open innovation have always intercepted the debate on the relationship between innovation and sustainability in a marked way, especially when addressing its environmental facet. Thus, it is not surprising that some companies have decided to combine the two models, giving rise to what is now called sustainable open innovation. The concept of sustainable open innovation is quite a recent one, and in the literature, there are different expressions of this topic, such as open eco-innovation, open environmental innovation or open eco-innovation mode [5]. Although these terms are used as synonyms, each of them refers to a particular nuance of the interaction between sustainability and open innovation. For this reason, our study aims to perform a comprehensive literature review on the intersection between these two concepts. In addition, scholars from different disciplines and countries have shown increasing interest in the intersection of open innovation and sustainability, justifying the need to synthesize existing research in order to understand the context, results, and main lines of future research. To date, there are several literature reviews investigating the relationship between open innovation and sustainability, which differ in scope, sector or period considered. Some reviews focus on the conceptualization of open eco-innovation [5,6], the one of Rauter et al. [7] have dealt with collaboration by investigating the role of stakeholders, the one of [8] framed open sustainable innovation in a specific sector, i.e. the agri-food one, while the review of Nielsen et al. [9] focused on the end-user. Nevertheless, the previously conducted reviews cannot be claimed to be exhaustive, as the research landscape on open innovation and sustainability is constantly changing and expanding. A Scopus search conducted by pairing the two terms found that 2021 was the most prolific year, while as of today, May 2022, 24 articles have already been published on the topic that could confirm or refute findings previously reported but not included in earlier reviews. Therefore, in order to explore the evolving aspect of the literature on the subject, it is appropriate to ask questions such as: how is the research regarding the interplay between open innovation and sustainability evolving? What are the main areas of interest? How are they interrelated? What future research themes can be inferred from studies on the topic? What are the key journals, the most contributing authors and countries, and the main managerial and organizational theories discussed?

This article aims to fill these gaps by outlining the intellectual structure of the research field.

A bibliometric analysis on a sample of 93 scientific articles published between 2011 and today, May 2022, has been conducted. To achieve the purpose of this review, both quantitative (co-occurrence analysis) and qualitative (in-depth analysis of the articles belonging to the sample with consequent identification of the main macro-topics addressed) were conducted.

The remainder of the paper is presented below. Section 2 introduces the theoretical background, Section 3 presents the methodology adopted, Section 4 discusses the findings while Section 5 presents conclusions and limitations of the research.

2. Theoretical Background

2.1. Sustainable Innovation

Innovation and sustainability are two closely interlinked concepts as innovation enables organizations to achieve higher levels of sustainability in their activities. Innovation can take different forms. In relation to the concept of sustainability, a distinction can be made between traditional innovations, i.e., those that contribute to an improvement in

corporate sustainability through, for example, process innovations and innovations oriented towards sustainable development, i.e., those that have a sustainable aim as their ultimate goal; e.g., the introduction of a new product that requires fewer resources. In the literature, these innovations have a multitude of different labels such as sustainable innovations [1], eco-innovations [10], green innovations [11], environmental innovations [12], sustainability-oriented (or related) innovations [13] or sustainable development innovations [14]. A study has previously distinguished three forms in which sustainable innovation can take place: technological, organizational and social [4]. The first form (technological) concerns the creation of a new product, process or service, or the modification of an existing one with the specific aim of reducing its environmental impact. The second form (organizational) concerns the modification of current company practices, implementing new ones capable of reducing the environmental risk linked to company activities, the pollution produced or the exploitation of non-renewable resources. The final aim is to operate not only without pursuing an economic objective but by introducing social and environmental objectives into business operations as well. Finally, the third declination is the social one, which concerns the development of new models of behavior, both at the level of the whole company and of the individual, aimed at approaching more sustainable lifestyles. Numerous scholars have studied sustainability linked to product or process innovations specifically. With regards to product innovations in particular, recent literature has pointed out that companies can develop sustainable innovation through radical or incremental innovations. The former requires a drastic change not only in processes but also in the company's mindset, while the latter is based on a constant and continuous change that slowly leads the company to incorporate sustainable practices in product development and realization [1].

2.2. Open Innovation

Open innovation can be seen as a new model of knowledge management that involves innovation processes characterized by openness towards the outside world, challenging the more conventional closed innovation model that has been adopted by companies until now. The term open innovation was officially born in 2003 with the publication of the book of the same name by Professor Henry Chesbrough of the University of California at Berkeley, who defined it as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively". The Open Innovation logic is varied and can include collaboration with external research centers, the active involvement of customers or suppliers or the possible transfer of internal research results, and even transforming internal development programs into open-source ones [15]. As the concept of open innovation began to take hold in the literature, it has been referred to with different, but overlapping terms, which have been used synonymously, although the meaning is slightly different. These include community-based innovation, crowdsourcing, user innovation or open-source innovation. It is possible to distinguish between two forms of open innovation, based on opposing processes: outside-in open innovation and inside-out open innovation. Inside-out is the process by which internally generated innovations are transformed into external business opportunities through e.g., licensing, spin-offs, patent sales and commercial joint ventures, etc. The second process, outside-in, allows the exploitation of externally generated innovations not only from traditional suppliers but from new alternative sources [16]. Inbound open innovation explores collaborations with other organizations to enhance a company's innovative capabilities. Naqshbandi et al. [17] argue that managerial ties play an important role in exploiting the valuable business information available in different markets to the organization's advantage. In fact, the term 'managerial ties' refers to relationships with suppliers, buyers, competitors, and other stakeholders (e.g., political officials or government organizations). Such ties can also help to improve the outcomes of outbound open innovation. Managerial resources, specifically managerial ties, with other organizations are important for acquiring, integrating, transforming, and using external resources.

Numerous scholars [18–20] have studied a correlation between firm size and collaboration with external partners in an open innovation context. In particular, differences can be found in the implementation of open innovation activities among micro, small, medium or large companies. In general, large companies are more involved in open innovation activities [21]. Large firms are more especially likely to develop collaborations with knowledge institutions, consulting firms or startups [22], while SMEs and micro firms resort to collaborations with strategic partners oriented toward increasing the chance of launching a new product or service. In this regard, Hossain et al. [20] argue that SMEs collaborate with external partners for marketing-related activities aimed at meeting market demand or maintaining competitiveness. Micro firms, on the other hand, are the most reluctant to collaborate with external partners for reasons that include a low propensity to share profits with other firms for development and launch of a new product or service [22].

2.3. Sustainable Open Innovation

The 2030 Agenda for Sustainable Development drafted by the UN in 2015 highlighted the urgency of achieving certain sustainability goals by 2030. However, implementing sustainable practices is not a simple task as there are numerous limiting barriers related to a wide range of factors such as the type of industry or the size of the company. Regarding the first factor, the more mature and innovation-unfriendly the industry is, the less inclined it is to move towards non-traditional topics such as sustainability or technological innovation [7]. For this reason, scholars have begun to investigate potential enablers for companies to support the sustainable transition. In particular, the key role of open innovation has emerged as it enables the development of new knowledge through the exchange of information, resources, knowledge and technologies between parties. For this reason, in the last decade, a strand of research has developed in the literature aimed at analyzing the role of open innovation in supporting the transition toward a sustainable business [23]. In the literature, the combination of the concepts of open innovation and sustainability is not unambiguously defined; rather, it is addressed using different terminologies. Rauter et al. [7] refer to it as “open innovation for sustainable innovation,” clarifying that it refers to the use of open innovation practices to bring elements of sustainability into business reality. Hossain et al. [20] use the term “open eco-innovation mode” to identify environmentally friendly ways of knowledge absorption and sourcing, collaborations with environmentally responsible partners, and the adoption of a green-oriented innovation system within the company. Chistov et al. [6] slightly modify this definition and propose the more generic term “open eco-innovation” to explain the purposive use of open innovation practices in the eco-innovation R&D process. Moreover, Brown et al. [24] started from circular economy studies to introduce the concept of “collaborative circular oriented innovation”, defined as the set of activities that integrate circular economy practices into technical and market-based innovation. Following the work of the authors in a study, in this article, we use the term sustainable open innovation to refer to the combination of open innovation and sustainability [25]. As such, sustainable open innovation is ascribed to the outside-in process as knowledge, skills and resources from outside support the development of sustainable innovation within the organization. The actors that are involved in the sustainable open innovation process can be divided into two groups based on the type of collaboration they offer: primary stakeholders and secondary stakeholders. The former is, for example, customers, consumers or employees, while the latter are communities, governments or NGOs, i.e., players who are not directly involved in market relations with the company [4].

3. Research Methodology

3.1. Data Collection

The present literature review has been conducted using bibliometric techniques as they are well suited to identifying the main research themes within a field of study and understanding the underlying theoretical foundations [26]. The review has been performed following a step-by-step process, which is displayed in Figure 1.

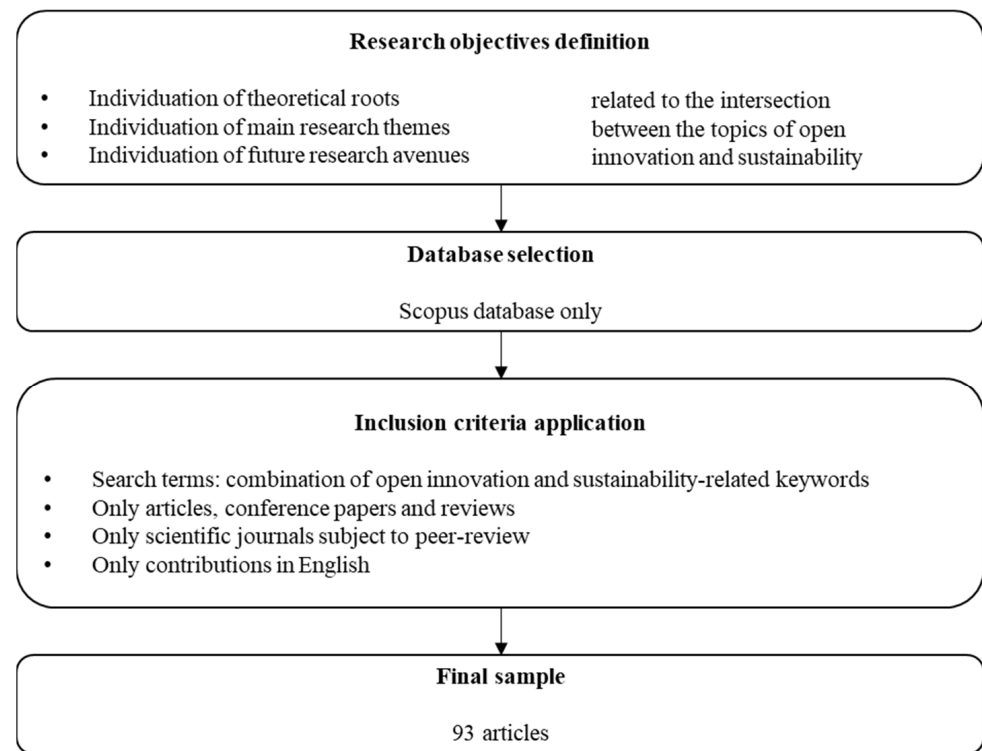


Figure 1. Article selection process.

First, the research objectives have been outlined. In particular, the aim of this work is that of understanding how the research regarding the interplay between open innovation and sustainability is evolving, what are the main areas of interest and how they are interrelated and what future research themes can be inferred from studies on the topic. To reach our goal, several steps have been followed. First, the database to be used for the analysis was selected. We chose Scopus since it is considered the most complete database in terms of scientific publications in peer-reviewed journals, ensuring the reliability of the results [27]. After that, the keywords to be included in the search string were identified in order to select the sample of articles to be analyzed. In order to include as many valid contributions as possible, the term “open innovation” has been combined with the different synonyms of sustainable innovation in the literature. In Table 1 the identified keywords and their combinations to conduct research are shown.

Table 1. Search keywords.

Sustainability-Related Keywords	Open Innovation-Related Keywords	Combination of Sustainability and OI
“Sustainab *”, “green innova *”, “environmental innova *”, “eco * innova *”, “green product innova *”, “green process innova *”, “circular economy”, “circular strateg *”	“open innova *”	“open eco-innova *”, “open eco innova *”, “sustainable open innova *”, “open sustainable innova *”, “open environmental innovation”, “open eco-innovation mode”, “open eco innovation mode”, “Open-corporate greening”, “Open corporate greening”, “open innovation”

*: the asterisk serves to consider as many words as possible with the same root.

Considering the scope of the analysis, the following inclusion criteria have been applied:

- Only articles, reviews and conference papers were retained in order to ensure the reliability of the sources;
- Only those contributions published in peer-reviewed scientific articles were considered;
- Only contributions in English were considered.

No specific time horizon has been selected. For completeness we report below the complete query entered: TITLE-ABS-KEY ("open eco-innova*" OR "open eco innova*" OR "sustainable open innova*" OR "open sustainable innova*" OR "open environmental innovation" OR "open eco-innovation mode" OR "open eco innovation mode" OR "Open-corporate greening" OR "Open corporate greening" OR ("open innovation" AND ("circular economy" OR "circular strateg*"))) OR (TITLE-ABS-KEY ("open innovation") AND TITLE-ABS-KEY ("sustainability-oriented innovation" OR "sustainability oriented innovation" OR "sustainable innova*" OR "sustainability oriented innova*" OR ("Sustainab*" AND ("green innova*" OR "environmental innova*" OR "eco* innova*" OR "green product innova*" OR "green process innova*"))) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")).

The application of the inclusion criteria allowed us to narrow the initial sample from 118 contributions to 93. The metadata of these publications were retrieved from Scopus in the formats needed to conduct subsequent analyses (.csv and .ris).

3.2. Bibliometric Analysis

This study employs bibliometric techniques aimed at providing a comprehensive overview of the object of study and exploring current research developments in this regard. The quantitative results are combined with qualitative investigations to confirm and deepen the findings. In particular, in order to answer the aforementioned research questions, a co-occurrence analysis of the abstract's words was done to identify the main research themes, as suggested by Beliaeva et al. [28].

Co-Occurrence Analysis

Co-occurrence analysis is a frequently used bibliometric method by which the relationship between two or more words is studied considering their co-occurrence in documents. Co-occurrence analysis may concern the words of the title or abstract, or a document's keywords [29]. The result is the development of a map built on the co-occurrences of terms that is able to represent the content of documents and, consequently, the cognitive structure of a given scientific field. It provides information about the main topics, i.e., the active research fronts in a given scientific field, from the network of correlations between "hot" or "emerging" topics [30]. To identify the main research topics, we conducted a co-occurrence analysis on the words of the abstracts using the VOS viewer software. The software analyzed the abstract words of the ninety-three articles in the sample from the .csv file retrieved from Scopus. A full counting procedure was considered and the minimum number of occurrences of a keyword was set at five, while the minimum number of items per cluster was set at ten to ensure effective relevance [31]. Before performing the analysis, it was appropriate to refine the data, following the prescriptions of Ding and Yang [29]: all terms not related to research areas, but rather to the structure of the publications, such as the type of document ("article", "conference", "paper", "book", "work", "review"), generic terms to indicate research ("analysis", "data", "research", "literature") or misleading terms such as "future research", "sample", "author", "keywords", or "managerial implications" were eliminated. This screening allowed us to use 87 terms.

4. Findings

4.1. Descriptive Statistics

Figure 2 illustrates the trend of the sample's publications over time. Two distinct phases can be seen, characterized by different scientific production. The first phase starts in

2011, when the first paper in the sample was published, and ends in 2018. In this first phase, scientific production settled around 3 publications per year, underlining a low level of interest in the topic of open innovation for sustainability. This is in line with the findings of Chistov et al. [6] and is due to the fact that the concept of open innovation had only recently been introduced. Consequently, the literature on the subject was nascent and sustainability topics only gained real interest from 2018 onwards.

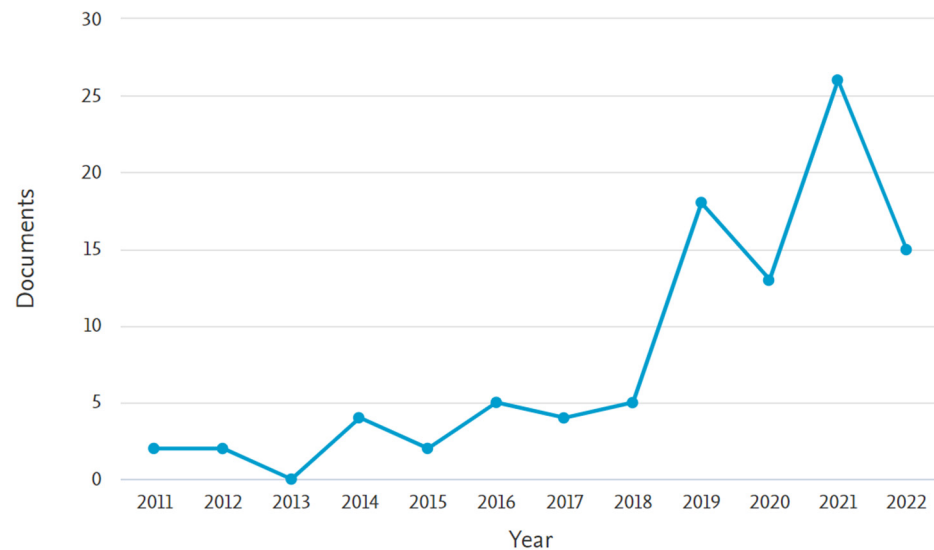


Figure 2. Publication trend.

Even though the research is spread over more than 40 scientific journals, three of them collect 46% of the overall contributions (Figure 3): Sustainability (Switzerland) (23 articles), Journal of Open Innovation: Technology, Market, and Complexity (10) and Journal of Cleaner Production (10).

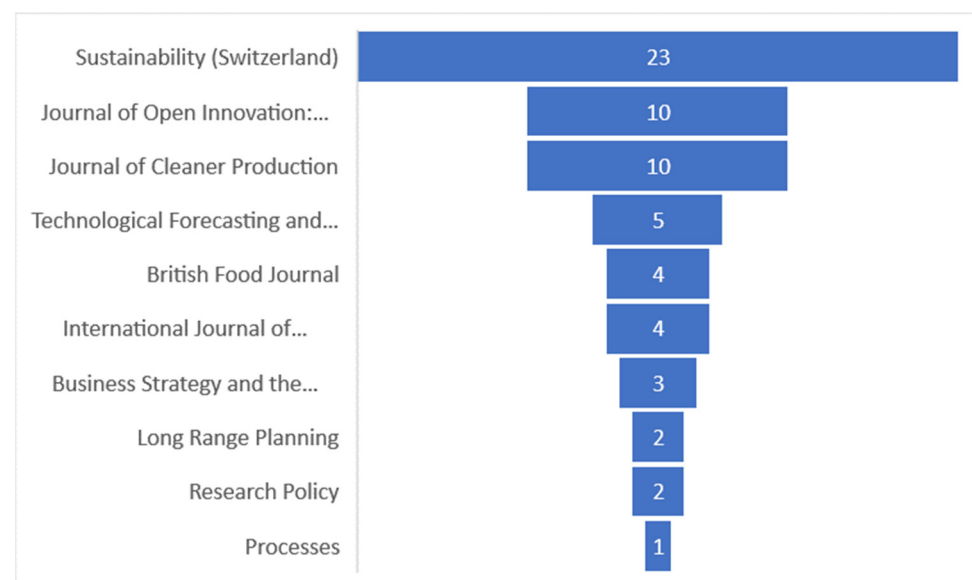


Figure 3. Top 10 contributing journals.

Tables 2–4 show the most active researchers, the most active countries and the main managerial and organizational theories discussed in the articles, respectively.

Table 2. Most active researchers.

Author	N. of Papers
Baccarne, B.	2
Baumgartner, R.J.	2
Behnam, S.	2
Bocken, N.	2
Bogers, M.	2
Cagliano, R.	2
Cappa, F.	2
Costa, J.	2
Fabrizi, A.	2
Füller, J.	2

Table 3. Most active countries.

Country	N. of Papers
Italy	21
Spain	10
UK	9
US	8
Denmark	7
Austria	6
Brazil	6
China	6
Germany	6
Netherlands	6

Table 4. Main managerial and organizational theories discussed in the sample.

Underpinning Theory	Reference
Resource-based view	e.g., [32–34]
Knowledge-based view	e.g., [35–37]
Organisational learning theory	e.g., [38,39]
Stakeholders' theory	e.g., [40]
Dynamic capabilities theory	e.g., [5,41]
Theory of planned behaviour	e.g., [42,43]
Absorptive capacity theory	e.g., [44,45]

4.2. Thematic Areas of Research

In order to identify the main research themes related to open sustainable innovation, a co-occurrence analysis was carried out on the words of the abstracts of the sample of articles. The result is the identification of a network formed by 87 nodes, represented by words extracted from abstracts and 1293 links, in which the items have been grouped by the software in four distinct clusters that correspond to the main research themes investigated. In Figure 4, the four identified clusters are shown graphically. The theme of each cluster has been identified by looking at the biggest nodes in each of them and deriving a common line of research. The first one deals with innovative performance in an open sustainable innovation context; the second one emphasizes the role of technological capability; the third one adopts a business model perspective focusing on the transition to a sustainable one; while the last one deals with the collaboration between companies and universities in order to produce sustainable innovation.

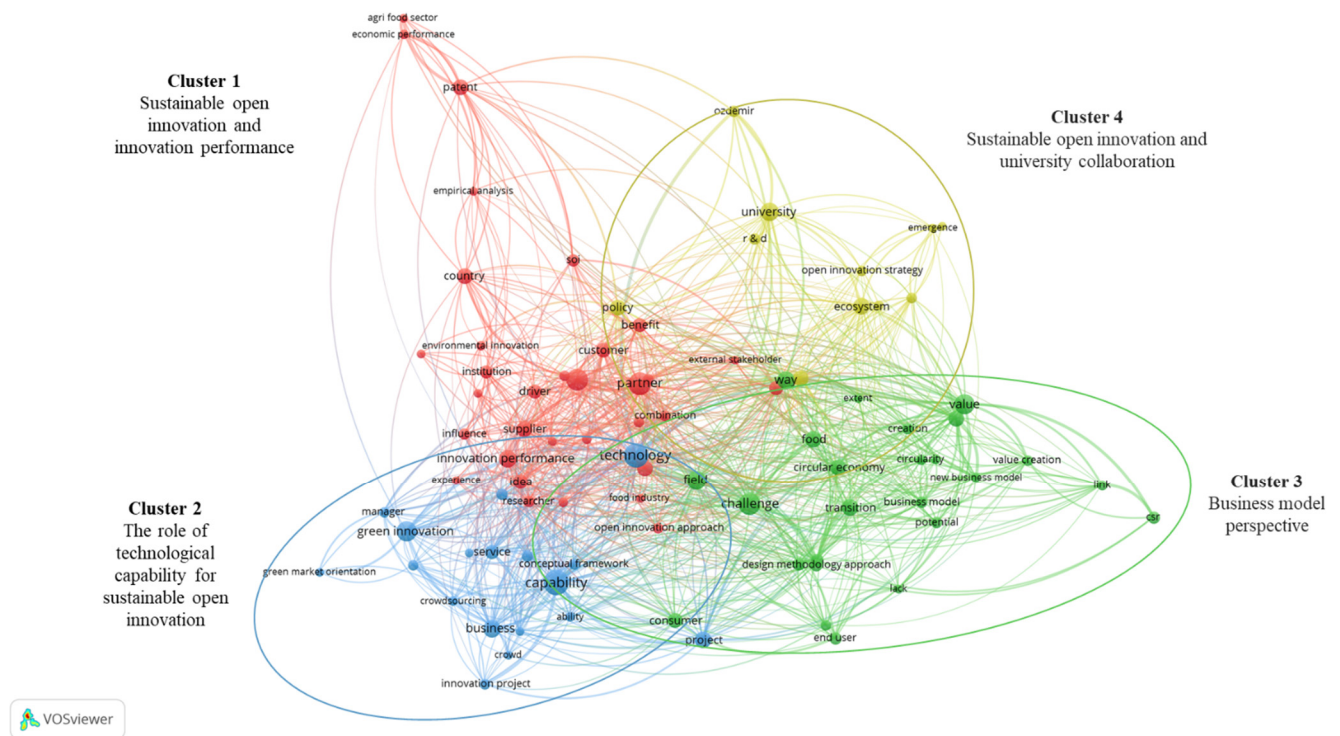


Figure 4. Word co-occurrence network based on the abstract of the sample articles.

4.2.1. Sustainable Open Innovation and Innovation Performance

Traditionally, when we talk about innovation and the need to innovate, the focus is on the tangible results that innovation enables us to achieve. In particular, until a few years ago the ultimate goal of an innovation process was that of improving the economic performance of the organization, measured in terms of increased revenues or margins, increased market share or improved customer satisfaction, which translates into a potential increase in sales [46]. However, the innovation process carries a whole range of consequences beyond the economic one, which is often not taken into account when measuring the economic success of an innovation program. These consequences are often not actively sought but result independently from the innovation process objectives, such as a reduction in environmental pollution or a decrease in the exploitation of new resources. Recently, given the increased attention around the topic of sustainability, as confirmed by the generation of an agenda of sustainability goals drafted by the UN in 2015, the assessment of innovative performance has started to integrate aspects that involve social and environmental dimensions in addition to the economic one [47]. Another element that influences the innovative performance of an organization is its degree of openness, understood as the propensity to collaborate with a network of external stakeholders for the specific purpose of developing innovation. Collaboration with external stakeholders, such as customers, suppliers, research centers, universities or even competitors, has a positive effect on the sustainability dimension related to the innovation process. Specifically, Rauter et al. argue that fruitful collaboration with external partners can increase the sustainable innovation performance of an organization, which is defined as the result of innovation activity related to the sustainable design of a product, the efficiency of a process to reduce resource consumption, the decrease of environmental pollution and the improvement of social conditions [7].

4.2.2. The Role of Technological Capability for Sustainable Open Innovation

Resource-based view theory gives us an indication of the resources and capabilities that can provide the organization with sustainable competitive advantages over time [48]. Specifically, resources can be different in nature and are classified into tangible, intangible

and human resources, while capabilities refer to a firm's ability to apply its resources effectively to undertake productive activities. Among the capabilities contemplated by the resource-based view theory, technological capability is considered one of the most relevant because it guarantees a sustainable competitive advantage. Technological capabilities, in fact, allow the improvement of the product or service to increase its value, as well as to improve business processes in order to reduce the costs incurred to implement them [49]. They refer to a firm's ability to perform any relevant technical function, such as the ability to develop new products, processes, or technologies, in order to achieve higher levels of organizational efficiency [50]. Several scholars have pointed out that technological capability is an element that can foster and accelerate the innovative activity of companies [51]. Recently, with the emergence of new production models and the change of direction by consumers, who are now more inclined to make more sustainable purchasing choices, companies are moving towards the adoption of new business models capable of incorporating the ecological and social dimensions. In this regard, innovative business models are based on technological capabilities, open innovation capabilities (understood as the ability to incorporate external actors for conventional innovations [51]) and ecological sustainability [52]. In particular, technological capability is a driver of business innovation in the same way as new disruptive technologies that allow knowledge and information to be gathered from customers, suppliers, competitors, universities or research centers via digital tools that enable direct two-way interaction. One example is the use of crowdsourcing platforms that connect a plurality of participants. Crowdsourcing, in fact, uses "IT to outsource any organizational function to a strategically defined population of human and non-human actors in the form of an open call" [53]. It may involve online consumer groups and brand communities and includes formats such as innovation contests on virtual co-creation platforms. As such, it is a valuable tool in an open innovation context, which requires the interaction of different stakeholders [54].

4.2.3. Business Model Perspective

The business model (BM) is an abstract concept that describes the logic by which a company creates value, emphasizing what its value proposition is, who the recipients are, and how it captures the value generated [55]. The concept of value can be looked at not only from an economic perspective but also from a sustainability perspective, according to which, the logic by which a company creates value should consider the integration of social and environmental goals [56]. Social and environmental value creation in recent years has become of fundamental importance to an organization. In particular, the former is seen as the main driver of social entrepreneurship, while the latter is the basis of so-called environmental entrepreneurship, focused on solving environmental problems while pursuing economic outcomes [57]. Reducing pollution, distributing resources equitably, reducing waste and abating poverty are some of the elements of sustainability that can be adopted by companies as strategies to incorporate the sustainability dimension into their business. More generally, companies interested in including the combination of economic, environmental and social aspects in their business can be said to be making a transition to a sustainable business model. Lüdeke-Freund et al. and Schaltegger et al. define the sustainable business model as "A business model for sustainability helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries", [58,59] (p. 6). Adopting a sustainable business model requires innovation. In fact, companies that want to incorporate the sustainability dimension must adopt an innovation perspective that is not limited to a mere modification of the supply chain, but rather involves a radical change in the way the company creates value. On that note, business model innovation can take several forms: designing a totally new business model from scratch, transforming an already existing one, acquiring a new business model and diversifying through additional business

models [55,60]. Resorting to open innovation is considered by scholars a viable strategy to operate a business model of innovation so as to incorporate elements of sustainability into it. Indeed, adopting an open innovation strategy in relation to sustainable business models means establishing a network of collaborative relationships with external partners, customers or user communities in order to improve the implementation of sustainability practices. Collaboration with a plurality of different stakeholders allows the generation of different solutions. In addition, collaborating implies sharing resources for a common purpose, so open innovation helps establish new ways to leverage organizations' excess capacity [60].

From a conceptual point of view, open innovation and business model innovation represent two different types of organizational change, since both forces the company to make changes. Open innovation, in fact, stimulates the company to make its boundaries more permeable, allowing the entry of knowledge flows from outside [61].

4.2.4. Sustainable Open Innovation and University Collaboration

As open innovation and sustainable innovation are two closely related concepts, the outcomes of their combination differ according to the type of industry, the size of the organization (start-ups, SMEs, multinational corporations, etc.), and the degree of openness of the company. The higher the degree of openness of a firm, the more likely it is to collaborate with a variety of external actors to produce innovation. In the literature, scholars agree that the impact of collaboration on innovation depends both on the type of actor with whom the company collaborates and on the type of innovation being undertaken. Furthermore, there is a consensus among scholars in the literature that there are substantial differences between types of partners that determine how collaboration is managed and what type of innovation can be achieved [62]. The specific characteristics of each partner can ensure different innovation outcomes. Nieto and Santamaria [63] stated that collaborations with customers and suppliers allow for greater knowledge of markets, new technologies and process improvement, impacting both product and process innovation. Collaborations with competitors, on the other hand, occur when companies experience common problems, and in some cases, they may lead to product innovation. Finally, collaborations with universities, research institutes or research centers have as their most frequent output the achievement of technological innovation, which in most cases allows for the opening of new markets or segments. Although collaboration positively influences sustainable innovation [64], the final outcome depends on the type of partners. Among the different stakeholders that can be involved in the open innovation process, the role of universities is relevant. Collaboration between universities and industry is particularly virtuous, as the former brings knowledge, skills and technologies to the latter, making collaboration seem as a tool to address not only economic but also social and environmental challenges [65]. Collaboration with universities provides access to national and international knowledge networks, in which their public partners are included. Moreover, another advantage of such cooperation is the contribution of complementary resources, which companies could not otherwise possess whether that be financial, human, or knowledge and technology. For this reason, universities are considered key partners for companies interested in embracing the sustainable innovation model. Moreover, in addition to providing complementary resources, universities allow access to funding projects from public bodies [66]. As far as open innovation is concerned, the university is present in the 'Triple Helix' model proposed by Etzkowitz [67], together with industry and government. It argues that these three entities can jointly participate in solving a problem, each contributing the resources and knowledge it possesses. Subsequently, further models were developed from the Triple Helix, characterized by a defined number of helices based on the actors involved in the specific innovation process. In particular, in the triple helix model and in the subsequent n-helix models, the university assumes a fundamental role as a producer of knowledge and an active player in the promotion of innovation. Zhou and Etzkowitz [68] argue that the enoble-helix model is effective in the production of innovation aimed at achieving

Table 5. The most recent terms used in the sample of articles.

	Avg Publication Year	Total Link Strength	Occurrences	Links
Economic performance	2021	83	6	11
Agri-food sector	2022	75	5	6
Crowd	2021	57	5	19
Combination	2021	99	7	34
Circularity	2021	85	7	18
Food industry	2021	40	5	19
Eco innovation performance	2021	55	5	8
Green innovation behavior	2021	135	5	13
Enterprise sustainable innovation	2021	30	5	6
Circular business model	2021	80	6	14

Open Sustainable Innovation in the Agri-Food Industry

In the last decades, the agri-food industry has become one of the most important sectors in the world. Recently, it has faced challenges that are no longer only economic but also, and above all, social and environmental [69]. First, consumers' lifestyles have changed dramatically. They started to be more concerned about their health, hence they began to express a preference for healthier food products. In this context, food quality and food safety have become two relevant factors driving consumer choices, forcing agribusiness companies to come up with new offerings. Second, the sustainability dimension and related environmental issues are posing a major challenge for the agri-food sector, which has felt the urgency to introduce sustainable practices at all stages of the value chain [25]. This is compounded by the fact that food systems are at the heart of twelve of the seventeen Sustainable Development Goals proposed by the United Nations in 2015 [70]. Several scholars have explored food systems under the lens of sustainable development, for instance Chaudary et al. [71] conducted a global-scale analysis to quantify the state of national food system performance in 156 countries, defining seven domains of sustainability: nutrition, environment, food accessibility and availability, sociocultural well-being, resilience, food safety, and waste. The theme of sustainable innovation, therefore, fits well with this new need, proposing a solution to a pressing issue. Indeed, sustainable innovation requires a paradigm shift for companies that decide to use it. Not only do they have to change their products or the way they are made, but they also must subvert their values and philosophy. In order for the agri-food industry to incorporate economic, social and environmental sustainability principles into the various stages of the value chain, a major effort is required on the part of organizations to convert to such a change. In fact, the agri-food industry is considered a relatively mature one, characterized by low levels of investment in R&D and very conservative in terms of the type of innovations to be proposed to the market. This means that the introduction of radically new products to the market is rare, while it is more common to find incremental innovations of existing products. This approach to innovation keeps R&D costs low, involves little technological risk, and encourages a large number of different products to be brought to market in a relatively short time. The result is the launch of only "slightly new" products, of which the final consumer has difficulty perceiving the added value [72]. For these reasons, innovating to move towards a sustainable horizon is a difficult challenge for this sector. In this regard, the literature recognizes open innovation as a valid approach that players in the agri-food industry can use to incorporate the sustainability dimension into their operations [73]. Open innovation in the agri-food industry sees brilliant examples of application. [74] outline several adoption models involving universities, research centers, competitors, suppliers, companies operating in different industries or innovation intermediaries. These models involve players in the agri-food industry at different levels of the supply chain, from food production to food distribution and consumption. Open innovation can therefore act as a facilitator to incorporate sustainable practices in the agri-food sector. In this regard, the role of digital technologies is crucial. Resorting to new digital technologies has enabled

the agri-food industry to increase the number of collaborations with partners, ensuring that companies can gather more information from both internal processes and external sources. This gives companies the opportunity to learn more about their suppliers, with whom they can initiate fruitful collaborations, and about consumer preferences so that they can satisfy them with targeted products and avoid putting products on the market that are destined not to be purchased. Being able to perfectly meet market demands not only allows companies to increase profits but also helps enhance sustainability as it decreases waste [75]. Crowdsourcing platforms are a useful digital tool for achieving this purpose since they foster opinion sharing on digital platforms. They serve to connect consumers, who through the sharing of their ideas, foster the development of new products that are more adherent to their needs, but they can also be used more broadly if a company wants to achieve greater sustainability goals. In fact, through these platforms, agri-food companies can potentially collaborate with all stakeholders in the supply chain in order to promote solutions that meet current market demands without compromising resources for future generations. Thus, it is clear that digital technologies represent a viable tool to implement successful sustainable open innovation strategies [25]. As far as crowdsourcing is concerned, it represents not only a source of information and knowledge useful for the creation of products more adherent to market demands but also an alternative way to finance sustainability-oriented initiatives. This is especially the case with crowdfunding, which is a financing method by which different actors can contribute economically to a project by collecting resources on digital platforms. This opportunity is mainly exploited by micro or SMEs that do not have access to large amounts of capital to innovate, giving them the opportunity to successfully implement sustainable open innovation strategies. In general, the size of agribusinesses is a relevant factor regarding sustainability-oriented open innovation strategies [76]. However, the literature studying the impact of this variable in the agribusiness sector is scarce. Future research could engage in studying how firm size affects the open innovation strategies adopted by agri-food firms with a view to sustainability. The goal is to understand whether the agri-food industry deviates from or follows the trend found at the general level. Building on this theme, it might be interesting to investigate whether firm size can break down rigidities due to the high culture of confidentiality that characterizes the agri-food industry when it comes to adopting an open innovation approach. Another interesting line of research could be based on the study by Bigliardi and Galati [74]. In fact, the authors presented a review of the main models of open innovation adopted by companies operating in the agri-food supply chain. In particular, the “Sharing is Winning” model involves the creation of strategic partnerships with key suppliers, startups, universities and research centers. The concept of co-development is at the core of the model, developed on three different levels: universities and research centers, startups and key suppliers. A possible line of future research may involve the in-depth study of collaborations at each level in order to understand how they can foster the achievement of sustainability goals.

5. Discussion

The research themes identified through the bibliometric analysis do not represent clusters with clear and distinct boundaries but leave room for overlaps, schematically shown in Figure 6, that give rise to virtuous discussion. Several studies [77,78] confirm the relationship between technological capabilities and innovation performance, justifying the overlapping of clusters 1 and 2. Wu et al. [77] in particular argue that a firm’s technological capability promotes eco-innovations, that is, innovations that drive toward sustainable development, reduce impacts on the environment and promote efficient and responsible use of natural resources. Wu [79], on the other hand, considers technological capability a key determinant of increasing product innovation performance when there is a collaboration with competitors, also called co-opetition. The relationship between technological capability and innovation performance has also been studied by Lau et al. [78], who verified how learning capability and resource allocation contribute to improving the per-

centage of sales due to product innovation, considered a proxy for innovation performance. This result provides supporting evidence for the importance of technological capabilities on innovation.

Moreover, technological capabilities are closely related to innovative business models. The business model, in fact, is itself a subject of innovation. Business model innovation, as previously explained, is a type of organizational innovation that allows the company to exploit available alternatives in terms of product, technology and process in order to create new value propositions. The ultimate goal of such innovation may be the company's need to access new markets, generate new sources of revenue or, as in the case investigated in this work, incorporate the dimension of sustainability. Technological capabilities, in fact, imply the ability of the firm to develop new designs, products, knowledge and skills in a unique way. Their possession by the company represents a facilitator to the business model innovation process [80].

Business model innovation requires the application of organizational design and governance skills that incorporate dynamic resources and capabilities to explore new business opportunities and ensure the company achieves organizational sustainability. Specifically, inter-organizational collaborations are success factors that foster and facilitate the implementation of business model innovation. In this regard, the triple helix model and its subsequent versions can also be applied in this context, emphasizing how the role of external stakeholders can be a source of innovation toward a more sustainable business model. As previously stated, one of the main components of these models is the university as a provider of knowledge, skills and technologies [81].

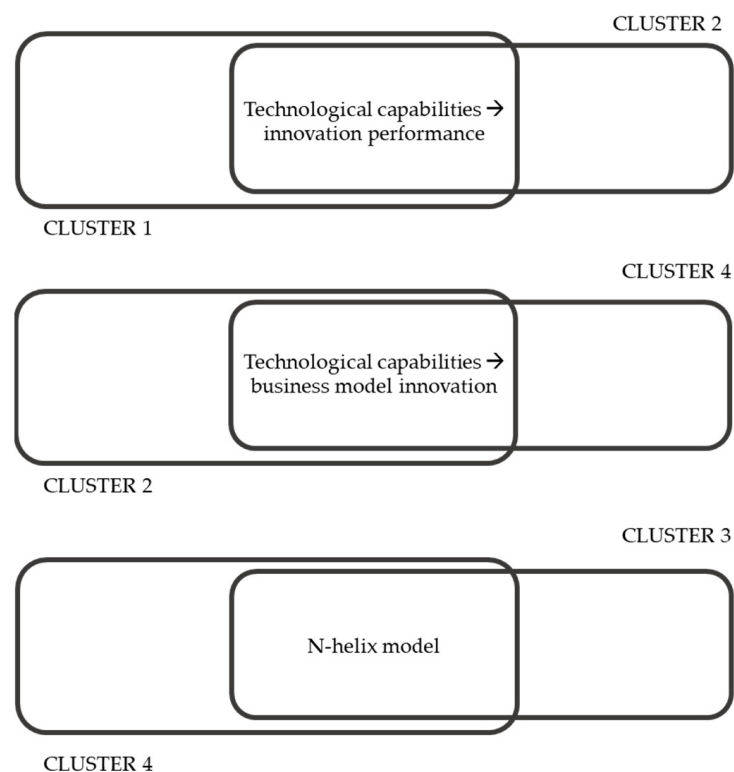


Figure 6. Overlapping themes among clusters.

5.1. Comparison with Previous Literature Reviews

Several reviews of the literature on the topic have been conducted, summarized in Table 6.

Table 6. Previous literature reviews.

Reference	Year	Scope	Methodology	Study Type	Time Span	N. of Articles	Main Results
[9]	2016	sustainable end-user innovation	Systematic literature review	qualitative	1992–2015	84	Identifies two strands of research: policies that provide end-users with resources to innovate; policies that facilitate the integration of end-users knowledge into an existing framework.
[6]	2021	open eco-innovation	Systematic literature review and bibliometric analysis	quantitative and qualitative	1990–2020	538	Proposes an unambiguous definition of open eco-innovation and identifies the main clusters of topics, differentiating them by level of analysis (micro, meso, and macro) Highlights developments over time in research regarding open eco-innovation and analyzes the knowledge base of open eco-innovation based on the type of external knowledge source. The emerging themes found are: green absorptive capacity, circular economy and eco-innovation intermediation.
[5]	2022	open eco-innovation	systematic review and bibliometric analysis	qualitative and quantitative	1999–2021	288	Proposes a new definition of healthy food using the sustainable open innovation approach that combines technology, innovation and sustainability.
[8]	2021	sustainable open innovation in the agri-food sector	systematic literature review and bibliometric analysis	qualitative and quantitative	1995–2021	198	Examines the role of open innovation in the adoption of the circular economy, with a specific focus on organizational theories, factors to overcome CE implementation barriers and OI application at meso and macro levels of CE.
[82]	2021	Open innovation and Circular Economy	systematic literature review	qualitative	2016–2020	24	Identifies the main issues discussed in the literature regarding the integration of open innovation and sustainability: collaboration for product development, knowledge management, R&D, firm network.
[83]	2021	Open innovation for sustainability	bibliometric analysis	quantitative	2003–2019	3087	Identifies the key stakeholders involved in the innovation process, both internally and externally to the company.
[7]	2017	Open innovation for Sustainable innovation	literature review	qualitative	2003–2015	19	

This article aims to outline the intellectual structure of this research field. In order to understand how the results obtained in terms of clusters fit into the existing literature, a framework (Figure 7) was developed that relates our results to those obtained from previous reviews. In particular, for the development of the framework, only reviews addressing sustainable open innovation (expressed with different terminologies considered as synonyms, as reported in Section 2.3) were considered. For this reason, the review conducted by Pontieri et al. [8] has been discarded as it was declined by the agri-food sector and focused on a specific product, sorghum. The review conducted by Nielsen et al. [9] was not used as well, as it does not deal with the topic of open innovation for sustainability from a general point of view but focuses on a specific actor in the context of open innovation, i.e., the end-users, thus lacking generalizability. As can be seen from the figure, we used the model presented by Chistov et al. [6] for the schematization of the results. The authors distinguish three different levels of analysis: macro-level, relating to society and the natural environment; meso-level, relating to the stakeholders outside the organization; micro-level, relating to the organization.

Regarding the macro-level, Cgistov et al. [6] and Jesus and Jugend [82] emphasize the positive effect of industrial symbiosis on sustainable open innovation, while Sanni and Verdolini [5] stresses how the concept of circular economy, declined in its main strategies (reuse, refurbishment, remanufacturing and recycling), should be studied together with that of open innovation to solve global problems such as the reduction of waste generated by the excessive consumption of both renewable and non-renewable resources.

Concerning the meso-level, most reviews emphasized the importance of the role of collaboration with external stakeholders. In particular, the results from Chistov et al. [6] and Rauter et al. [7] highlighted the relevance of collaboration with suppliers and other companies, both from the same sector (competition) and not. Another important topic is collaboration with consumers or end-users, the effect of which was a result of the reviews conducted by Rauter et al. and Payán-Sánchez et al. [7,83] on sustainable open innovation. In particular, Payán-Sánchez et al. [83] highlights the role of crowdsourcing as a result of sustainable open innovation. Further findings from previous reviews are the importance of knowledge management when it comes to collaborating with external partners [6], the role of research and development [83] and the intermediation to connect suitable external partners to the company [5]. The result obtained in cluster 2 fits into this context, enriching it with additional information. In fact, collaboration with universities did not emerge as a result from any of the previous reviews.

The micro-level, on the other hand, focuses on the organization. Firms' capabilities and competences emerged as an outcome in several reviews. Chistov et al. [6] consider them from a general point of view, emphasizing how they can determine the innovative outcome of a sustainability-oriented company. Rauter et al. the competences and capabilities most conducive to sustainable open innovation are absorptive capacity, openness in knowledge relationships and corporate strategy and culture, while Sanni and Verdolini [5] specifically identified green absorptive capacity [7]. Therefore, the result obtained from our review in cluster 4 ('Role of technological capability') is in line with the previous results since technological capability emerged as a driver of sustainable open innovation. Regarding performance, Ref. [82] found that sustainable innovation increases organizational performance. Payán-Sánchez et al. come to a result in line with our review by emphasizing the link between sustainable open innovation and innovation performance [83].

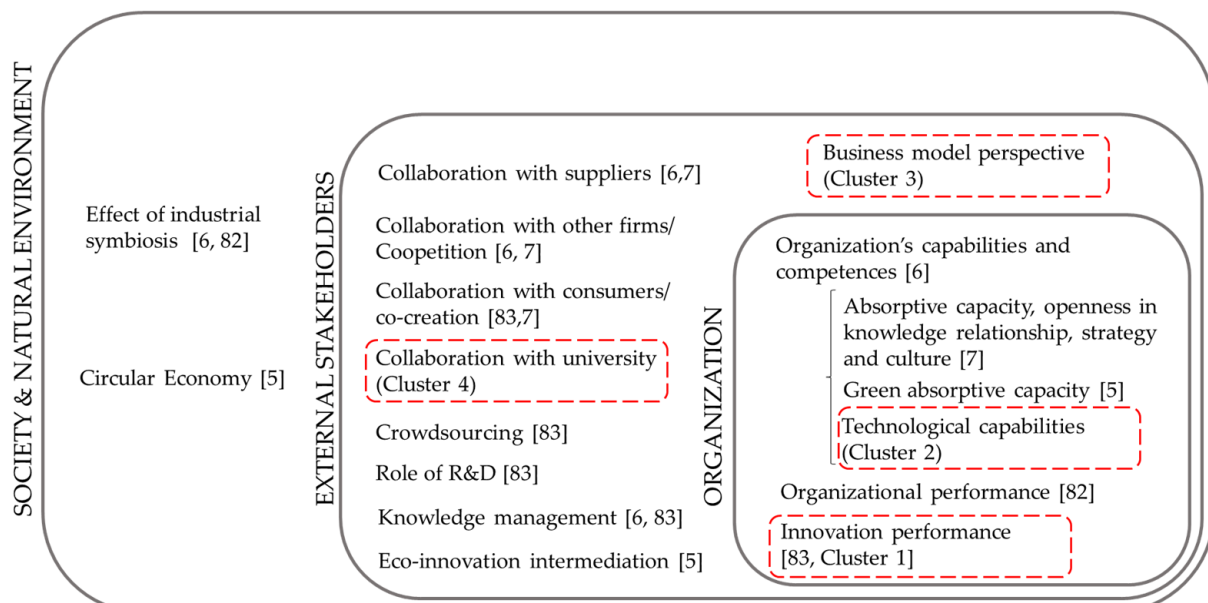


Figure 7. Comprehensive framework of literature reviews' results.

5.2. Managerial Implications

Today, if a company wants to remain competitive in the market, it must learn to innovate while increasing the triple bottom line. This means that managers and employees must learn to innovate in view of today's global sustainability challenges [84]. From a practical point of view, this inevitably entails a change within the company, which must implement sustainable practices within its current business model, both for the sake of the environment and society as well as for strictly economic reasons. As highlighted by the results of the bibliometric review, innovating the business model is a response to this need. To do so, companies must first better understand the current business model, then identify the actions necessary to integrate sustainability practices into it, and only then can it innovate in order to implement them. The main implication for business strategy in this regard is the company's understanding of the challenges involved in adopting a business model that incorporates sustainability dimensions.

Secondly, the paper suggests that collaboration between different stakeholders fosters sustainable innovation. Indeed, collaboration is one of the pillars on which open innovation is based and its importance was first emphasized by the triple helix model, and subsequently by its updated versions. One of the main elements underpinning the helix models is the university, which is regarded as a source of knowledge, skills and technologies crucial for innovation. In order to integrate sustainability into the business context, managers must foster collaboration between university and industry, making it an ongoing practice and effectively integrated into business processes rather than an occasional event.

6. Conclusions and Limitations

This study aims to summarize the developments in the field of sustainable open innovation as it is a rather recent and scarcely investigated research topic. The aim is to identify the main research themes, as well as potential future lines of research. Based on quantitative bibliometric techniques and a qualitative literature review, this article provides several considerations on the current state of research on sustainable open innovation. The co-occurrence analysis identified four well-defined thematic clusters: sustainable open innovation and innovation performance, the role of technological capability for sustainable open innovation, business model perspective, and sustainable open innovation and university collaboration

As far as future research is concerned, a mainline has been identified concerning the study of sustainable open innovation in the agri-food industry.

The present study shows some limitations. Firstly, the choice of using a single database, namely Scopus, was motivated by the need to obtain reliable results, but on the other hand, it certainly caused the exclusion of contributions that could have been interesting. Secondly, the filters used to select the documents further limited the sample; in particular, by only allowing us to analyze articles, reviews or conference papers in English published in a scientific journal. The omission of these inclusion criteria would have allowed us to include in the study contributions that could potentially have altered the results we arrived at. Moreover, another limitation of our study lies in the choice of keywords in the query used to select the sample of articles. In fact, only the term open innovation was used, leaving out expressions referring to the same concept such as innovation ecosystems, creative process, triple helix, cross-functional teams or agile management. Adding these keywords in the computerized search could have enlarged the sample and affected the results obtained. However, this is a valuable starting point for an update of the present literature, providing a useful directive for future research development.

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