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Driving eco-innovation in supply chains through multi-stakeholder collaboration: A review and research agenda

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ABSTRACT

This article examines the concept of eco-innovation (EI) and its role in achieving sustainable economic growth by integrating environmental and social considerations. It focuses on identifying key practices and relationships that promote EI in supply chains through multi-stakeholder collaboration. By systematically reviewing existing literature, the article highlights the challenges and opportunities of implementing eco-innovative practices. It emphasizes the importance of collaborative networks, including companies, suppliers, universities, governments and civil society, in facilitating EI within supply chains. The findings aim to assist firms and practitioners in comprehending the crucial concepts and relationships related to eco-innovation in supply chains. The article serves as a comprehensive overview of the importance of eco-innovation, the role of collaborative networks and multi-stakeholder engagement and the need to adopt a holistic approach to drive eco-innovative practices in supply chains for sustainable economic growth. Additionally, the article suggests potential areas for future research in this field.

1. Introduction

To address the escalating global challenges, including the unsustainability of the current linear economic model and the increasing environmental degradation, a transition towards more sustainable practices has become imperative. One of the most promising approaches is the adoption of a circular economy (CE), which emphasizes minimizing waste and optimizing resource use to achieve sustainable development (Berlin et al., 2022; Walker et al., 2022). Within this context, eco-innovation (EI) emerges as a pivotal strategy, offering a pathway for achieving economic growth while simultaneously reducing environmental burdens and fostering social sustainability (European Commission, 2022; Rennings, 2000).

The significance of EI lies in its dual objective of environmental sustainability and economic performance enhancement. The European Union, for example, has actively promoted EI as a means to optimize resource utilization and minimize companies' environmental impact (European Commission,2022). EI encompasses the introduction of new or significantly improved products, processes, organizational changes, or marketing solutions that reduce the use of natural resources and minimize harmful substances throughout the life cycle (EIO (EIO (Eco-Innovation Observatory)) 2010). Originally introduced by Fussler and James (1996), the concept of EI has since evolved to integrate organizational and marketing changes (Viale et al., 2022), thus broadening its applicability across industries. Notably, EI fosters value creation for stakeholders while addressing environmental concerns, making it a cornerstone of sustainable business strategies (Díaz-García et al., 2015 Hojnik and Ruzzier, 2016).

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The theoretical foundation of EI is deeply rooted in the principles of sustainability and innovation theory. Sustainability emphasizes the balance between economic, environmental, and social dimensions, as outlined in the Sustainable Development Goals (SDGs). Goal 9 (Industry, Innovation, and Infrastructure) and Goal 12 (Responsible Consumption and Production) underscore the critical role of innovation in achieving sustainable practices. EI serves as a vehicle for translating these theoretical principles into actionable strategies, helping firms mitigate environmental degradation while enhancing competitive advantage (Cassetta et al.,2022).

From an innovation theory perspective, EI represents a fusion of technological and organizational advancements aimed at achieving environmental objectives. It aligns with the concept of "open innovation," which emphasizes leveraging external knowledge and collaborative partnerships to drive breakthrough innovations (Chistov et al., 2023; Pichlak and Szromek, 2021). This framework highlights the interdependence of firms, governments, academic institutions, and other stakeholders in co-creating innovative solutions that address pressing environmental challenges.

The supply chain (SC) plays a critical role in the successful implementation of EI. The SC represents the interconnected network of activities, resources, and relationships involved in producing and delivering goods and services. Effective SC management ensures the seamless integration of sustainability principles throughout production, distribution, and consumption processes (Bag et al., 2022; Crișan et al., 2021). The involvement of SC partners in EI activities enables firms to address systemic barriers such as resource constraints, technological gaps, and knowledge deficits (Gatignon and Xuereb, 1997). It also ensures that eco-innovative practices and strategies are implemented and disseminated from the beginning to the end of the chain. Engaging in SC collaborations can help drive EI, as it enables information exchange and resource optimization (Crișan et al., 2021; Peng and Lin, 2022), following the rationale that conjointly two (or more) partners can develop solutions for some environmental problems (e.g. Crișan et al., 2021; Hofman et al., 2020).

Collaboration within the SC is pivotal for fostering both incremental and radical eco-innovations. Vertical collaborations, involving suppliers, customers, and internal functional units, facilitate knowledge sharing and alignment of sustainability goals (Simatupang and Sridharan, 2002). Horizontal collaborations, encompassing partnerships with competitors and other organizations, expand the scope of innovation by pooling resources and fostering industry-wide advancements (Melander and Arvidsson, 2022). These inter-organizational relationships are underpinned by trust, information exchange, and joint problem-solving efforts, creating a conducive environment for EI development (Silva and Moreira, 2021; Zimmermann et al., 2016).

Given the imperative of stakeholder involvement in eco-innovative product or process development to address barriers and access additional knowledge, EIs typically follow an open innovation paradigm (Giacomarra et al., 2020; Ocicka et al., 2022). EIs involve proactive behavior in managing interactions and collaborations with SC partners and quadruple helix actors, enabling the acquisition of knowledge from external sources and its integration among internal stakeholders (Cassetta et al., 2023). Collaborations with external actors such as governments and universities are also necessary to identify environmentally friendly innovative solutions that address society's urgent challenges, thus acting as drivers of EI (Cassetta et al., 2023; Crișan et al., 2021). As such, interest in supply chain eco-innovation has rapidly grown. Previous literature reviews have addressed SC innovation in general, identifying green SC collaboration and EI as prominent areas within green SC management, particularly in the context of sustainable development (Malacina and Teplov, 2022). Other systematic reviews have explored more specific aspects, such as green innovation networks, emphasizing the need for further research on horizontal collaborations to better understand how firms engage in EI (Melander and Arvidsson, 2022). Additionally, Hamam et al. (2023) focus on EI within a specific collaborative system, industrial symbiosis, analyzing its application in the agri-food sector (Hamam et al., 2023). These literature reviews highlight the pivotal role of collaborations in achieving environmental and sustainable development through green or eco-innovation. Studies addressing the topic of EI from a SC perspective also investigated the importance of collaboration with both downstream and upstream actors (e.g. Hofman et al., 2020), such as the importance of supplier-customer collaborations (Ocicka et al., 2022), inter-firm relationships (e.g. Ramkumar, 2022) or industrial symbiosis (e.g. Hamam et al., 2023) on EI development and adoption.

Despite extensive research on the role of collaboration in fostering EI, existing studies often focus on specific types of relationships (e.g., vertical or horizontal) or particular sectors (e.g., agri-food). This fragmented approach limits our understanding of how multi-stakeholder collaborations are arranged and their overall significance for the SC. There is a need for a comprehensive synthesis of the literature to identify and categorize the key thematic areas related to multi-stakeholder collaborations in driving EI within SCs. This study addresses this gap through a systematic literature review (SLR), aiming to:

1. Identify and categorize the main thematic areas emerging from the literature on multi-stakeholder collaborations and their role in fostering EI.
2. Provide an interpretative analysis of these themes to highlight best practices and key factors influencing the success of EI activities in SC management.

To achieve these objectives, the study seeks to answer the following research question: *What are the key thematic areas regarding the role of multi-stakeholder collaborations in fostering eco-innovation in supply chains?*

This research contributes to the existing body of knowledge by offering an integrated perspective on multi-stakeholder collaborations in SCs, emphasizing their role in driving EI. It aligns with SDG Goal 17, (Partnerships for the Goals), which advocates for collaborative approaches to achieving a sustainable planet (United Nations, 2015). By synthesizing insights from diverse studies, this review provides practical guidance for firms and practitioners aiming to implement effective EI strategies across SCs, addressing barriers such as resource constraints and knowledge deficits. Ultimately, the study aims to enhance the understanding of collaborative dynamics, enabling firms to translate sustainability principles into operational practices.

This paper is organized as follows: After this introduction, Section 2 presents the methodology. Section 3 provides the characterization of our sample. Section 4 discusses the thematic groups identified, using Hoshin Kanri's X-matrices to visually identify, categorize and synthesize the articles included in each thematic group. Section 5 presents the conclusions and provides an illustrative summary that synthesizes this review's main findings, aiming at assisting firms and practitioners in successfully implementing EI practices within SCs. Finally, Section 6 provides directions for future research.

2. Methodology

This paper follows a systematic literature review (SLR) method to assess and develop the current knowledge base regarding the research question posed (Tranfield et al., 2003). By employing a systematic and explicit approach in the selection of the manuscripts, the SLR method enables the production of a transparent and rigorous review, distinguishing it from traditional narrative reviews (Tranfield et al., 2003), Additionally, the SLR method offers valuable insights into potential future research avenues. We adopted a three-step methodology, as proposed by Tranfield et al. (2003), for data collection and a comprehensive evaluation of the topic under analysis: (i) planning the review (defining the review's objective and research question); (ii) conducting the review (identifying relevant literature, detailing inclusion and exclusion criteria); and (iii) reporting and disseminating the results. This

three-step methodology is similar to the PRISMA guidelines for reporting systematic reviews, which was also utilized to enhance transparency, rigor and replicability (Madhavan et al., 2022, Page et al., 2021).

Regarding the first step, the objective of this review was stated in the introduction section. The second step addresses both inclusion and exclusion criteria to ensure transparency and replicability of this review (Denyer and Tranfield, 2009). Finally, Section 3 reports the results and Section 4 discusses the major thematic groups identified in this review. Table S1, utilizing the PRISMA 2020 Main Checklist, and Table S2, with PRISMA Abstract Checklist, give transparency to the whole process and result.

This SLR employed an interpretative synthesis and evaluation approach, following Jones et al. (2011), which is considered a best practice when conducting SLRs as it is possible to follow the principles of inductive thematic analysis and informal ontological classification.

The Scopus database was utilized to locate relevant studies as it provides a reliable scientific database with a strong focus on research articles, conference papers, reviews, books and book chapters (Abdulhayoglu and Thijs, 2018; Mongeon and Paul-Hus, 2016). It has a stringent review evaluation process, when compared to other databases as Google Scholar, ensuring the inclusion of high-quality, peer-reviewed content (Martín-Martín et al., 2018). In the *Strategy and Management* field, it has a Lin's concordance correlation coefficient of 96.43 % with the Web of Science (WoS) database (Pech and Delgado, 2020).

The search employed a combination of two keyword categories, namely "supply chain" and "eco-innovation," which were applied to the title, abstract and keywords of articles. To cover all possibilities, we used the terms "supply chain* " and "eco-innovat* ". The search was limited to articles and reviews published in peer-reviewed English language journals. To identify all potentially relevant studies on this topic, we

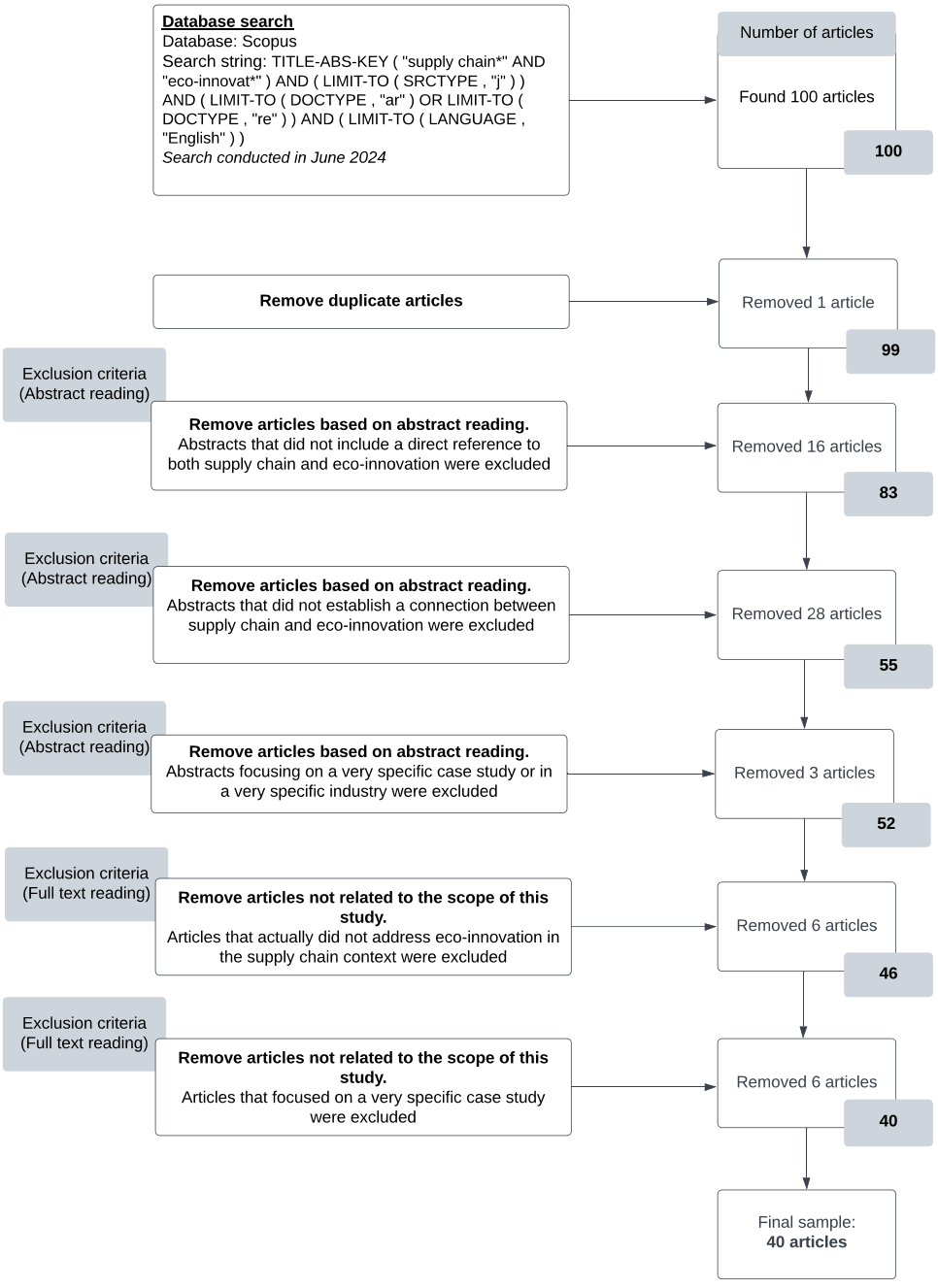

Fig. 1. Representation of the identification and selection process in this SLR.

placed no time restrictions. This search yielded a total of 100 articles. We then extracted the abstracts, keywords and other citation information and exported them to an Excel spreadsheet. This allowed the authors to individually identify potential studies for inclusion in this review and facilitated the monitoring of article selection and analysis. One duplicate article was removed from the list.

To aid the literature search and, subsequently, the data analysis, we used two protocols. The protocol for conducting the review included the procedure for searching, selecting and excluding articles (Jones et al., 2011; Tranfield et al., 2003). Subsequently, after reading the abstracts, several articles were excluded based on Jones et al. (2011) and Tranfield et al. (2003): (i) did not directly refer to both SCs and EI; (ii) failed to establish a connection between SCs and EI, indicating a lack of focus on eco-innovation in supply chains; (iii) concentrated on highly specific case studies, with no added value for this study; or (iv) conducted within narrow industry contexts, thereby preventing generalization. This step resulted in a set of 52 articles, which were downloaded for thorough reading. Based on the full-text assessment, 12 articles that were not relevant to the scope of the study were excluded. To guide the exclusion process, we employed two criteria: (i) articles that did not actually address EI in the SC context; and (ii) articles that focused on highly specific case studies. Consequently, we arrived at a final sample of 40 articles that were selected for in-depth content analysis. Figure 1 provides an overview of the identification and selection process.

Once selected the 40 articles to include in the subsequent analysis, we adopted an informal, qualitative–interpretative ontological approach, just as recommended by Bouncken et al. (2021) and Chandrasekaran et al. (1999), in order to give meaning and to catalog the main thematic findings under analysis, based on the various companies analyzed, the context in which the analysis took place, the types of activities taking place and the objects and conceptualizations provided. As a result, the following four broad thematic groups were object of further analysis:

- Key challenges and drivers of eco-innovation in supply chain management;
- Inter- and intra-organizational relationships within the SC;
- The importance of partnerships and institutional pressures in the SC ecosystem;
- Eco-innovation and circular economy: Sustainable supply chain practices.

3. Characterization of the sample

This section presents a descriptive analysis of the articles included in this SLR, focusing on global and local citations, date of publication, publication sources and thematic groups identified. This analysis seeks to provide a better contextualization of the research topic.

Table 1
Final pool of articles included in this SLR.

No	Authors	*Journal*	Best quartile*	TGC	TLC
1	Afshari et al. (2020)	*Int. J. Production Economics*	Q1: Bus, Manag and Accounting	61	4
2	Ansari and Kant (2021)	*Int. J. Sust. Engineering*	Q1: Engineering	7	1
3	Arfaoui (2018)	*Applied Economics*	Q2: Economics and Econometrics	20	1
4	Bag et al. (2022)	*Journal of Business Research*	Q1: Marketing	117	2
5	Blasi et al. (2015)	*J. on Chain and Network Science*	Not yet assigned quartile	21	0
6	Cao et al. (2023)	*Int. J. of Logist. Res. Applic.*	Q1: Bus and Int Management	6	0
7	Cassetta et al. (2023)	*Industry and Innovation*	Q1: Bus, Manag and Accounting	9	0
8	Costantini et al. (2017)	*Journal of Cleaner Production*	Q1: Environmental Science	231	8
9	Crișan et al. (2021)	*Int. J. of Environmental Research and Public Health.*	Q2: Health, Toxicology and Mutagenesis	4	0
10	Dewick and Foster (2018)	*Ecological Economics*	Q1: Economics and Econometrics	23	3
11	Dharmayanti et al. (2023)	*J. of Open Innovation: Technology, Market, and Complexity*	Q1: Development	21	0
12	do Canto et al. (2021)	*Management of Environmental Quality*	Q1: Biochemistry, Genetics and Molecular Biology	24	0
13	Giacomarra et al. (2020)	*EuroMed Journal of Business*	Q1: Bus, Manag and Accounting	52	0
14	Hamam et al. (2023)	*Frontiers in Sustainable Food Systems*	Q1: Agronomy and Crop Science	7	0
15	Hasler et al. (2016)	*Sustainability (Switzerland)*	Q1: Geogr, Plann and Development	20	0
16	Hofman et al. (2020)	*Business Strategy and the Environment*	Q1: Bus and Int Management	70	5
17	Hsu et al. (2016)	*Int. J. of Operations and Production Management*	Q1: Decision Sciences	196	4
18	Jabbour et al. (2015)	*Int. J. of Production Economics*	Q1: Bus, Manag and Accounting	139	4
19	Kerdpitak et al. (2020)	*Int. J. of Supply Chain Management*	Not assigned quartile * *	1	0
20	Li et al. (2023)	*Int. J. of Production Economics*	Q1: Bus, Manag and Accounting	15	0
21	Lin et al. (2020)	*Journal of Cleaner Production*	Q1: Environmental Science	37	1
22	Mahdiraji et al. (2023)	*Journal of Cleaner Production*	Q1: Environmental Science	11	0
23	Malacina and Teplov (2022)	*Int. J. of Production Economics*	Q1: Bus, Manag and Accounting	22	0
24	Maranesi and de Giovanni (2020)	*Sustainability (Switzerland)*	Q1: Geogr, Plann and Development	57	0
25	Melander and Arvidsson (2022)	*Journal of Cleaner Production*	Q1: Environmental Science	28	0
26	Mylan et al. (2015)	*Journal of Cleaner Production*	Q1: Environmental Science	69	8
27	Ocicka et al. (2022)	*Energies*	Q1: Engineering	13	0
28	Orji et al. (2019)	*Transportation Research Part A: Policy and Practice*	Q1: Aerospace Engineering	51	3
29	Paletto et al. (2021)	*Annals of Silvicultural Research*	Q2: Forestry	2	0
30	Peng and Lin (2022)	*Sustainability (Switzerland)*	Q1: Geogr, Plann and Development	3	0
31	Ramkumar (2020)	*Sustainability (Switzerland)*	Q1: Geogr, Plann and Development	10	0
32	Rodríguez-González et al. (2022)	*Corporate Social Responsibility and Environ. Management*	Q1: Development	18	1
33	Roscoe et al. (2016)	*Journal of Cleaner Production*	Q1: Environmental Science	90	3
34	Shih et al. (2018)	*Sustainability (Switzerland)*	Q1: Geogr, Plann and Development	21	1
35	Simms et al. (2020)	*Journal of Cleaner Production*	Q1: Environmental Science	25	1
36	Song et al. (2023)	*Production and Operations Management*	Q1: Indust and Manufact Engineering	8	0
37	Tabaeeian et al. (2021)	*Int. J. of Logistics Systems and Management*	Q3: Inform Systs and Management	3	0
38	Tseng and Bui (2017)	*Journal of Cleaner Production*	Q1: Environmental Science	94	2
39	Viale et al. (2022)	*Supply Chain Management*	Q1: Bus, Manag and Accounting	13	0
40	Wang et al. (2022)	*Journal of Business Research*	Q1: Marketing	13	0

Notes: TGC: Total Global Citation (actual Scopus global citation); TLC: Total Local Citation (within the 40 papers); * This information was obtained from the SCOPUS database; * * Discontinued source from Scopus since 2020; The papers were ordered alphabetically. The number of the papers is going to be used to elaborate the Hoshin Kanri matrices.

3.1. Final pool of articles and citation analysis

Table 1 provides the final pool of articles selected for this SLR, including their total global citations (TGCs) and total local citations (TLCs). To construct this table, the TLC plot obtained from Bibliometrix software (Aria and Cuccurullo, 2017; Linnenluecke et al., 2020) was considered in conjunction with the TGCs corresponding to the overall SCOPUS citation count for each specific paper. The TLC score represents the frequency with which a paper has been cited by other papers within the set of 40 articles, which allows to assess the interconnectivity among the reviewed papers (Fahimnia et al., 2015). Upon scrutinizing the sample, it is possible to observe a substantial disparity between local and global citation scores, suggesting considerable interest from researchers in other scientific domains concerning the topic of EI in SCs. Consequently, the papers analyzed have received citations from articles outside our sample, demonstrating their impact on diverse research areas. Moreover, the presence of a low TLC alongside a higher TGC score underscores the potential interdisciplinary nature of this research stream, as these papers have garnered significant attention beyond their immediate field of study.

The ranking of papers based on TLC score only aligns with their TGC score in some cases. For instance, the paper authored by Costantini et al. (2017) has the highest global and total citation scores. Conversely, one of the most locally cited articles, authored by Mylan et al. (2015), is ranked 7th in terms of TGC.

3.2. Date of publication

The articles included in this review were published from 2015 to 2023. As shown in Figure 2, half of the reviewed articles (20 articles) were published in the last three years. This indicates that the research topic is relatively recent, as there has been a rapid growth in the number of papers since 2020, with a small decrease in publications in 2021. This publication trend clearly shows that this research field is in its growth stage, with an increasing number of articles being published and receiving an increasing attention from scholars. Chronologically, eight articles were published in 2015–2017 period, 12 articles were published in 2018–2020 period and 20 articles were published between 2021 and 2023.

3.3. Publication source

Regarding the main outlets, we found that 25 peer-reviewed journals address the research topic, as shown in Figure 3. Among these, only four journals have published two or more papers related to our review, namely: *Journal of Cleaner Production* (8 articles), *Sustainability* (5), *International Journal of Production Economics* (4) and *Journal of Business Research* (2). We notice a focus on business and management research areas, along with topics pertaining to sustainability. Nevertheless, some articles were published in journals with a specific emphasis on marketing, environmental science or engineering, which reveals a multidisciplinary approach to the study of eco-innovation in SCs.

3.4. Thematic groups and years of publication

The 40 articles selected for this SLR were aggregated into four thematic groups based on a qualitative-interpretative analysis of the manuscripts (Bouncken et al., 2021; Chandrasekaran et al., 1999). Table 2 organizes the articles by thematic group and year of publication. The thematic group 'Key challenges and drivers of eco-innovation in supply chain management' shows a consistency of publications from 2015 to 2023, suggesting an ongoing interest in this topic. In contrast, while research on 'inter- and intra-organizational relationships within the SC' began in 2015, it only gained significant traction from 2020 onwards, reflecting a growing interest in exploring the dynamics within and between organizations in a SC. Similarly, research on 'the importance of partnerships and institutional pressures in the SC ecosystem' has received particularly attention since 2020, indicating the importance of analyzing these aspects Lastly, 'Eco-innovation and circular economy: sustainable supply chain practices' shows a relatively continuous flow of publications from 2016 to 2023, with a higher number of publications in 2020. This suggests an increasingly significant focus on the application of circular economy concepts when analyzing SCs.

4. Discussion of the thematic groups

The aim of this section is to discuss the main thematic groups identified in this review. Based on an in-depth analysis of the reviewed articles, for each thematic group, a Hoshin Kanri X-matrix was designed to illustrate the main topics, data collection and data analysis methods and the countries and industries covered in each paper. The Hoshin Kanri matrix, also known as X matrix, traditionally recognized in the management field as a strategic planning tool for linking strategy to business execution (Silveira et al., 2018), is used in this study as a tool to facilitate the identification, categorization and synthesis of articles within each thematic group in a visual manner (Patrício et al., 2018). This approach aligns with strategies observed in previous systematic review studies (Moreira et al., 2024). The X-matrices have four customizable and interconnected building blocks, facilitating the analysis of the themes/sub-themes and cross-comparison of various study characteristics, enhancing this review's transparency and reliability (Patrício et al., 2018). Each X-matrix is organized alphabetically based on the papers included within each theme, as shown in Figures 4 to 7. The four thematic groups and their X-matrices are presented in the next sub-sections.

4.1. Key challenges and drivers of eco-innovation in supply chain management

The first thematic group, comprising 13 articles, is systematized in Figure 4. It shows a focus on the different challenges/barriers and the drivers associated with implementing EI in SCs. Regarding the methodology, the majority of these articles (7 out of 13) employ a quantitative method, collecting data whether through surveys or secondary databases, as shown in Figure 4. This thematic group also includes studies that use qualitative analysis, mix-methods and one SLR, thus

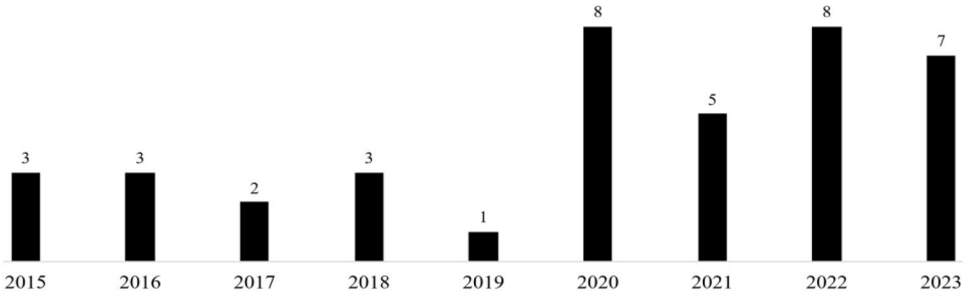

Fig. 2. Number of articles per year of publication.

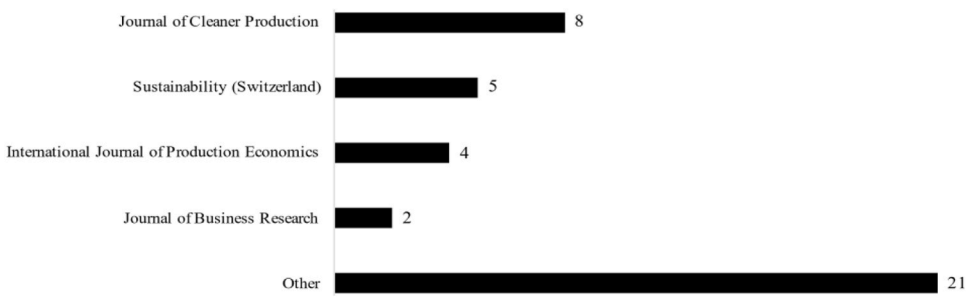

Fig. 3. Main sources of publication.

revealing the need to complement quantitative findings with deeper insights, enriching the understanding of EI challenges and drivers.

The rise of environmental concerns has exerted increased pressure on companies to adopt new strategies and develop innovative products with reduced impact on the environment. Sustainable practices in the SC have not only allowed cost savings but have also protected the environment from the negative impacts of businesses (Malacina and Teplov, 2022). Environmental innovation, often referred to as green innovation, has gained popularity in studies examining its impact on supply chain management (SCM) and sustainable development (Malacina and Teplov, 2022).

The adoption of EI necessitates significant transformations in the traditional SC model and numerous challenges arise when companies evolve to the "hands-on" stage. We have identified six main challenges in the implementation of eco-innovative practices in the supply chain: (i) economic and financial challenges (Ansari and Kant, 2021); (ii) strategic management challenges (Orji et al., 2019); (iii) organizational and leadership challenges (Orji et al., 2019); (iv) social challenges (Mahdiraji et al., 2023); (v) market-driven challenges (Ansari and Kant, 2021); and (vi) technological challenges (Simms et al., 2020). Among them, the most influential is the economic and financial challenges (Ansari and Kant, 2021). Implementing EI processes requires substantial resources, funds, research facilities, new skills, changes in production lines, procurement of environmentally friendly raw materials and adoption of new technologies (Ansari and Kant, 2021).

The second most influential challenge is strategic management. Companies must recognize the financial benefits of adopting EIs and define their research and development strategies (Orji et al., 2019). Organizational and leadership barriers emerge in third place, indicating that insufficient management support and commitment result in uncertainty when adopting green innovations (Orji et al., 2019). Companies require more education at the C-level to effectively develop new environmental technologies and establish successful business models (Ansari and Kant, 2021). Ecologically informed managers, environmental-driven teams and the full involvement of employees have been shown to lead to higher environmental performance (Jabbour et al., 2015). Moreover, in the early stages of development, empowering employees and securing management commitment are critical factors for the successful implementation of EIs (Jabbour et al., 2015), which relies on senior management support (Tabaeeian et al., 2021). The connection between EI and the top management team (TMT) has also been investigated, with a particular focus on TMTs' R&D experience, environmental management experience and SCM experience (Li et al., 2023). The relevance of executives' personal experiences and their backgrounds has been acknowledged and analyzed as moderators in the impact of subsidies on EI, being found that TMTs with R&D experience are inclined to allocate the subsidies on EI activities (Li et al., 2023).

Social barriers focus on supplier collaborations for the implementation of EI, wherein poor communication and alignment between partners pose significant challenges (Orji et al., 2019). Cooperation among suppliers allows companies to exchange resources, knowledge and technology while mitigating investment risks (Ansari and Kant, 2021). The creation of contractual categories with suppliers (e.g., Game Theoretical Coordination Contracts) enables them to engage with "appropriate" levels of commitment and varying degrees of intellectual sharing, fostering better collaboration between the parties (Mahdiraji et al., 2023). However, even with varying degrees of vertical cooperation, it may not be sufficient to overcome this barrier (Blasi et al., 2015). Market challenges, our fifth barrier, emphasize the willingness of customers to pay for greener products or technologies, which are often more expensive compared to environmentally unfriendly alternatives (Ansari and Kant, 2021). Finally, the technological barrier (or the lack thereof) highlights the need for new facilities, infrastructure and investments that are still poorly implemented in companies (Orji et al., 2019). For larger SCs, the testing and implementation of new technologies pose significant challenges in their decision to adopt EIs (Simms et al., 2020).

Based on the identified challenges, it was possible to identify three main drivers for the adoption of eco-innovations: (i) market demand; (ii) regulation; and (iii) company-specific characteristics, such as knowledge, technology and market positioning (Hasler et al., 2016). While some of these drivers may also be perceived as challenges, environmental regulations, such as European Regulation REACH (Registration, Evaluation, Authorization and Restriction of Chemicals), incentivize companies to seek new raw materials and "greener" suppliers, as well as explore production processes that reduce environmental impact and the presence of hazardous substances in final products (Arfaoui, 2018). REACH regulation encourages the adoption of EIs by requiring a continuous flow of information exchange throughout the SC, from suppliers to users (Arfaoui, 2018). However, to drive demand for more environmentally friendly substances, it is essential to extend producer responsibility, ensuring that downstream users are informed and motivated to adopt cleaner products (Arfaoui, 2018). Additionally, producers must ensure transparency in their supply chains, enabling the transfer of knowledge and responsibility to suppliers regarding green product development (Arfaoui, 2018).

The implementation of environmental innovation in SCM is crucial for companies to achieve sustainable development and secure a better world for future generations. Although technology is one of the top challenges in EI, it is also one of the best solutions for a successful transition towards sustainability by facilitating the assessment of the progress of new environmental processes (Costantini et al., 2017). Information technology, in particular, has been demonstrated to have a greater impact on EI than factors such as the organizational or the environmental context, significantly promoting the development of EI practices (Tabaeeian et al., 2021). In fact, digital adaptability can be a way for companies to effectively leverage technologies, enhancing their EI efforts and capabilities, as digital technologies facilitate data utilization, information sharing and foster collaborative innovation (Dharmayanti et al., 2023). The roles of managers, suppliers, governments and customers are crucial in overcoming some of the challenges mentioned in this section. In the following sections, we will explore in detail how these relationships and collaborations can act as game-changers in decision-making processes.

Table 2
Thematic groups and year of publication.

Year of publication	2015	2016	2017	2018	2019	2020	2021	2022	2023
Key challenges and drivers of eco-innovation in supply chain management	Blasi et al. (2015) Jabbour et al. (2015)	Hasler et al. (2016)	Costantini et al. (2017)	Arfaoui (2018)	Orji et al. (2019)	Simms et al. (2020)	Ansari and Kant (2021); Tabaeeian et al. (2021)	Malacina and Teplov (2022)	Dharmayanti et al. (2023); Li et al. (2023); Mahdiraji et al. (2023)
Inter- and intra- organizational relationships within the SC	Mylan et al. (2015)			Dewick and Foster (2018)		Giacomarra et al. (2020); Lin et al. (2020); Ramkumar (2020)	do Canto et al. (2021)	Bag et al. (2022)Melander and Arvidsson (2022); Ocicka et al. (2022); Viale et al. (2022)	Song et al. (2023)
The importance of partnerships and institutional pressures in the SC ecosystem				Arfaoui (2018)		Hofman et al. (2020)	Crișan et al. (2021); do Canto et al. (2021);Paletto et al. (2021)	Bag et al. (2022);Peng and Lin (2022)	Cassetta et al. (2023); Li et al. (2023)
Eco-Innovation and Circular Economy: Sustainable Supply Chain Practices		Hsu et al. (2016) Roscoe et al. (2016)	Tseng and Bui (2017)	Shih et al. (2018)		Afshari et al. (2020); Kerdpitak et al. (2020); Maranesi and de Giovanni (2020)		Rodríguez-González et al. (2022); Wang et al. (2022)	Cao et al. (2023); Hamam et al. (2023)

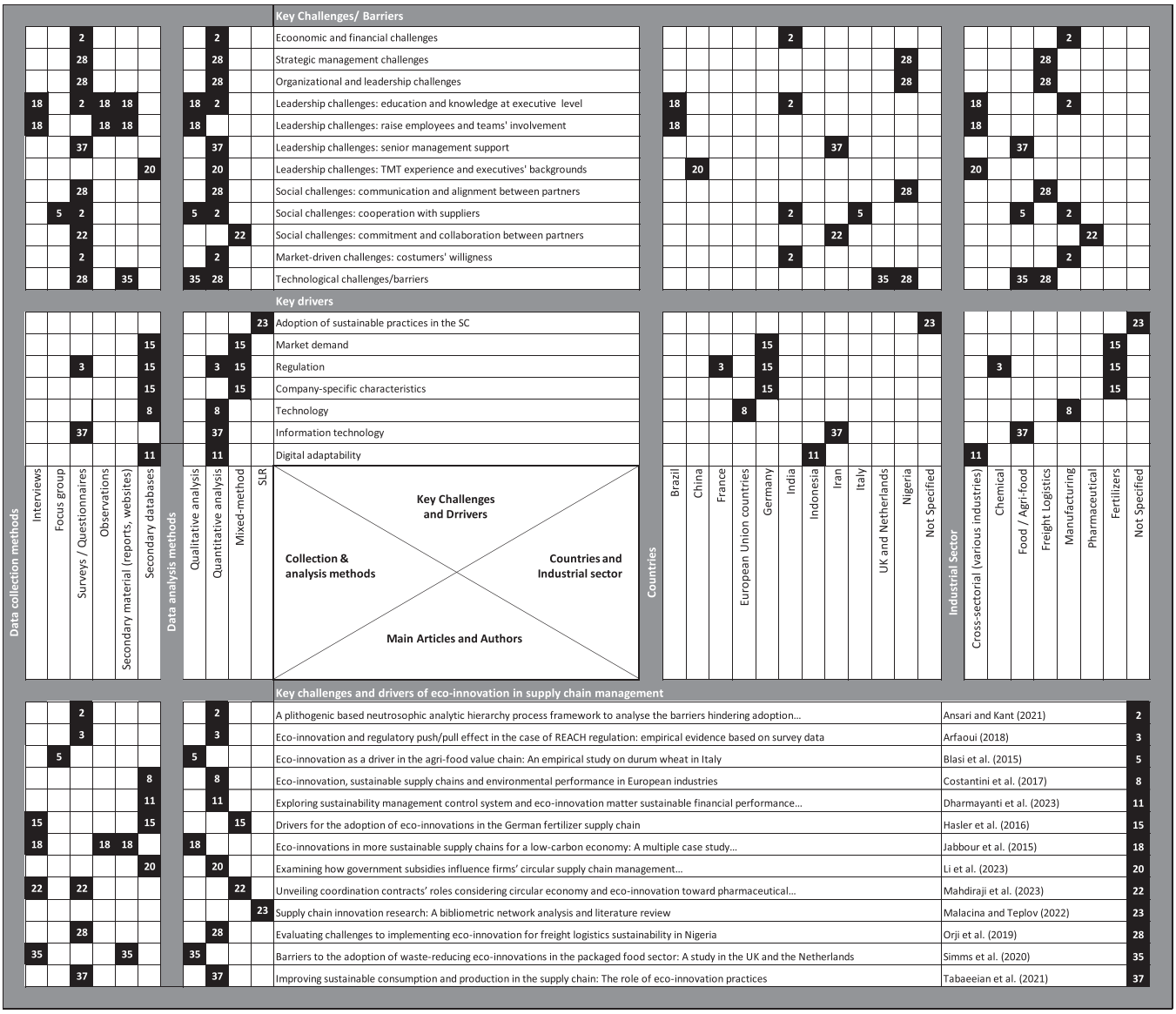

Fig. 4. Characterization of the thematic group "Key challenges and drivers of eco-innovation in SCM".

Several patterns stand out from this thematic analysis. First, the duality of challenges and drivers as they are interconnected, with some drivers (e.g., market demand or regulations) also presenting as barriers due to cost, complexity, or resistance (e.g., Tabaeeian et al., 2021). Effective knowledge transfer is both a barrier and an enabler, depending on the extent of institutional and organizational support (Arfaoui, 2018; Hasler et al., 2016). Second, the critical of leadership, particularly in R&D and environmental management and organizational structure as they shape the capacity to overcome challenges and seize opportunities for eco-innovation success (Orji et al., 2019). Third, collaboration is a central enabler and knowledge transfer is a catalyst for open EI to take place. Supplier collaboration and knowledge-sharing within the supply chain emerge as critical pathways for overcoming social and technological barriers (e.g. Ansari and Kant, 2021; Blasi et al., 2015; Simms et al., 2020). Strategic partnerships, contractual frameworks and information transparency are necessary for aligning diverse stakeholders toward EI goals (e.g. Mahdiraji et al., 2023). Vertical and horizontal cooperation can mitigate risks and amplify the benefits of EI efforts. For this open EI perspective to take place, the flow of information and knowledge across the supply chain mandatory, emphasizing the importance in reducing supplier misalignment and market readiness.

Fourth, regulations both drive and demand EI by requiring transparency and knowledge-sharing across supply chain actors. As such, compliance with environmental standards incentivizes firms to adopt green practices but also imposes operational and strategic pressures, particularly on smaller entities (e.g. Arfaoui, 2018; Hasler et al., 2016). Fifth, economic and financial barriers are consistently ranked as the most influential, underscoring the resource-intensive nature of eco-innovation, normally, involving high upfront costs for sustainable raw materials, technology adoption and production line transformation, creating a significant entry threshold for smaller firms (e.g. Ansari and Kant, 2021). Sixth, firms must balance green product development with market positioning and competitive pricing strategies if EI is to succeed. Seventh, eco-innovation implementation is dynamic in nature. As such, empowering employees and fostering a collaborative culture are critical in these early stages, while technology adoption and supply chain transformation dominate mature phases (e.g. Ansari and Kant, 2021; Orji et al., 2019; Jabbour et al., 2015). Finally, EI is framed as not merely a compliance requirement but a long-term strategy for sustainable development and competitive advantage (e.g. Ansari and Kant, 2021; Orji et al., 2019; Jabbour et al., 2015). It demands a long-term vision for sustainability involving a systemic shift in SCM.

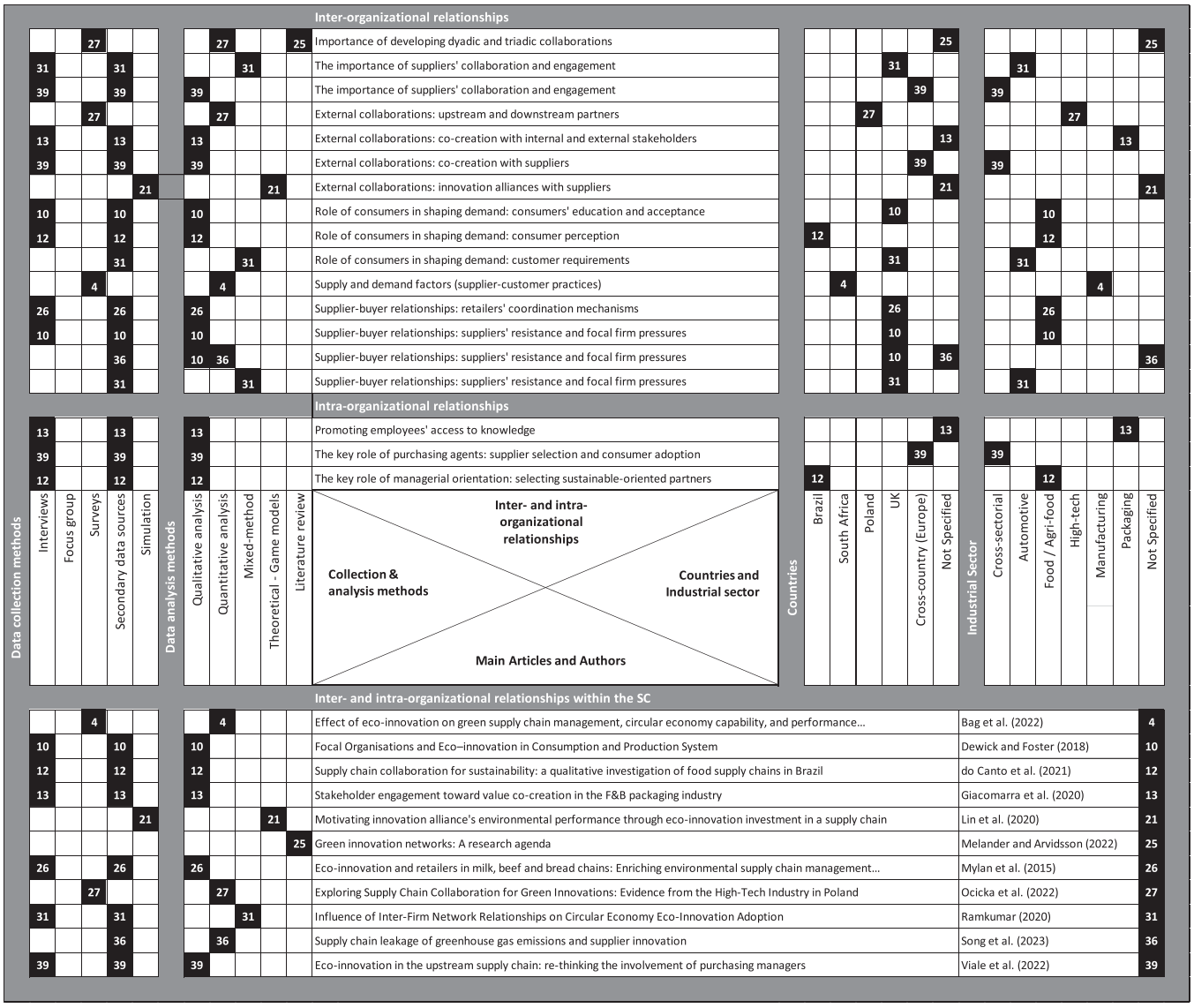

Fig. 5. Characterization of the thematic group "Inter- and intra-organizational relationships within the SC".

These patterns disclose that EI in the supply chain is multifaceted and interconnected, with solutions often emerging from strategic collaborations in which open innovation plays a tacit role, leadership commitment and regulatory alignment.

4.2. *Inter- and intra-organizational relationships within the SC*

A set of 11 articles, as shown in Figure 5, addresses the crucial role of interrelationships among various actors in the SC (from suppliers and sub-suppliers to customers) in the development and successful implementation of EIs (Giacomarra et al., 2020; Viale et al., 2022). As for the methodology, as illustrated in Figure 5, there is a clear predominance of qualitative analyses, with data collected through interviews and secondary sources. This predominance highlights the complexity of organizational relationships within the SC and the need to explore in-depth the dynamics, interactions and nuanced nature that shape relationship behaviors in this context.

EIs involve complex inter-firm networks among these actors (Ramkumar, 2020), extending beyond dyadic relationships to include triadic collaborations and cooperation across the entire SC (Melander and Arvidsson, 2022). These inter-organizational networks enable firms to create synergies, access greater capabilities and resources and reduce information asymmetry (Ramkumar, 2020). Hence, firms learn from one another, exchanging information, knowledge, skills and resources, which is crucial for driving EI by mitigating risks and costs (Ocicka et al., 2022; Ramkumar, 2020). The effective implementation of EIs requires long-term collaboration and a high level of communication amongst partners (Dewick and Foster, 2018; Viale et al., 2022), as well as an effective management of both internal and external stakeholders by the focal company (Giacomarra et al., 2020). The ultimate goal is to address the uncertainty associated with EI (Ramkumar, 2020), gain competitive advantage and have a positive impact on the economic, social and environmental performance of the all partners involved (Ocicka et al., 2022).

Collaborations are also essential for addressing both the complexity and uncertainty of today's competitive environment, in which no firm can build competitive advantage alone, and the current environmental issues (Ocicka et al., 2022). External collaborations bring greater environmental awareness, stimulating firms to develop EIs and ultimately promoting the adoption of circular practices throughout the SC (Ramkumar, 2020). As a result, innovation co-creation processes may emerge (Ocicka et al., 2022; Viale et al., 2022). For example, in food and beverage SCs, co-creation is crucial for addressing sustainability challenges by reducing the negative impacts of the industry on the

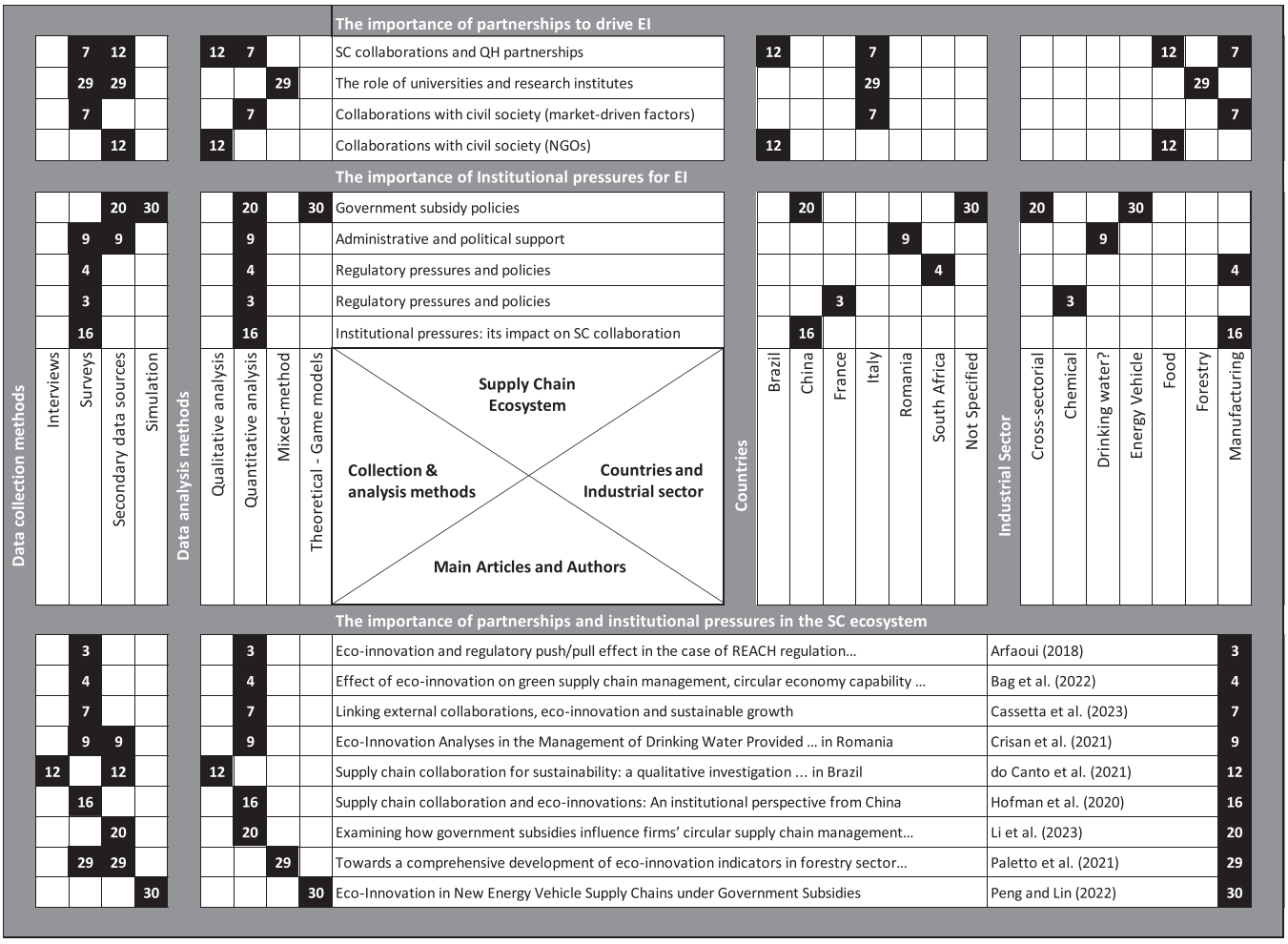

Fig. 6. Characterization of the thematic group "The importance of partnerships and institutional pressures in the SC ecosystem".

environment through the development of eco-innovative products, processes and practices (Giacomarra et al., 2020). So, EIs can follow an open mode of innovation, relying on the establishment of collaborative networks with external stakeholders, namely suppliers, bringing together various capabilities and sources of knowledge (Giacomarra et al., 2020). The lack of collaboration can act as a barrier to sustainability in the SC and can be mitigated by reinforcing cooperation among members, aligning their social capital and sustainability orientation (do Canto et al., 2021). For instance, focusing on regional partners with a sustainability orientation yields positive outcomes, as distant partners increase transportation costs and have more businesswise transaction-oriented relations (do Canto et al., 2021).

The inter-organizational relationships, particularly with upstream partners, play an important role in initiating the EI process, enhancing the focal firm's capacity to innovate (Mylan et al., 2015; Ramkumar, 2020; Viale et al., 2022). Supplier collaboration is a key source of external knowledge, facilitating the development and implementation of EIs by offering suggestions and the sharing of best practices (Viale et al., 2022). The implementation of EIs is dependent on suppliers' engagement, as demonstrated by the closed-loop recycling innovation implemented by Jaguar Land Rover (JLR) (Ramkumar, 2020). For JLR's REALCAR project, which involved replacing steel with recycled aluminum at every stage of automobile production, JLR needed to ensure the collaboration of suppliers for the collection of waste aluminum material (Ramkumar, 2020). In this case, collaboration with suppliers was more crucial than with other partners in accelerating the adoption of the EI across the SC (Ramkumar, 2020). Indeed, as EI often requires change in raw materials or components, companies are dependent on their suppliers' involvement, which increases the probability of success in the market (Mylan et al., 2015; do Canto et al., 2021).

In their relationships with suppliers, focal firms can leverage their bargaining power to encourage the adoption and implementation of EIs within the SC (Dewick and Foster, 2018). This can be achieved by establishing interactive supplier-buyer relationships and creating a knowledge hub to share best practices (Dewick and Foster, 2018). For example, in the REALCAR case, suppliers' resistance could have jeopardized the entire project (Ramkumar, 2020). So, JLR exerted a coercive pressure, leveraging its position as customers to demand suppliers to adopt the EI, even if they did not share the same financial and environmental benefits (Ramkumar, 2020). JLR also shared best practices among suppliers and provided financial incentives to alleviate the financial burden of implementing the project (Ramkumar, 2020). Similarly, Mylan et al. (2015) analyzed the role of supermarkets to boost upstream EI in agri-food SCs, highlighting the importance of collaborating suppliers, through coordination mechanisms such as economic incentives, information exchange or the development of eco-performance standards. Suppliers' degree of eco-innovativeness can also be assessed through certifications (Song et al., 2023). For instance, the European Regulation REACH in the chemical industry highlights the importance of a continuous flow of information exchange throughout the SC, from suppliers to users (Arfaoui, 2018). Hence, the demand side plays a key role in fostering and disseminating innovation among suppliers, driving imitation between partners through mimetic pressures (Bag et al., 2022). Fearing the loss of such an important client, suppliers

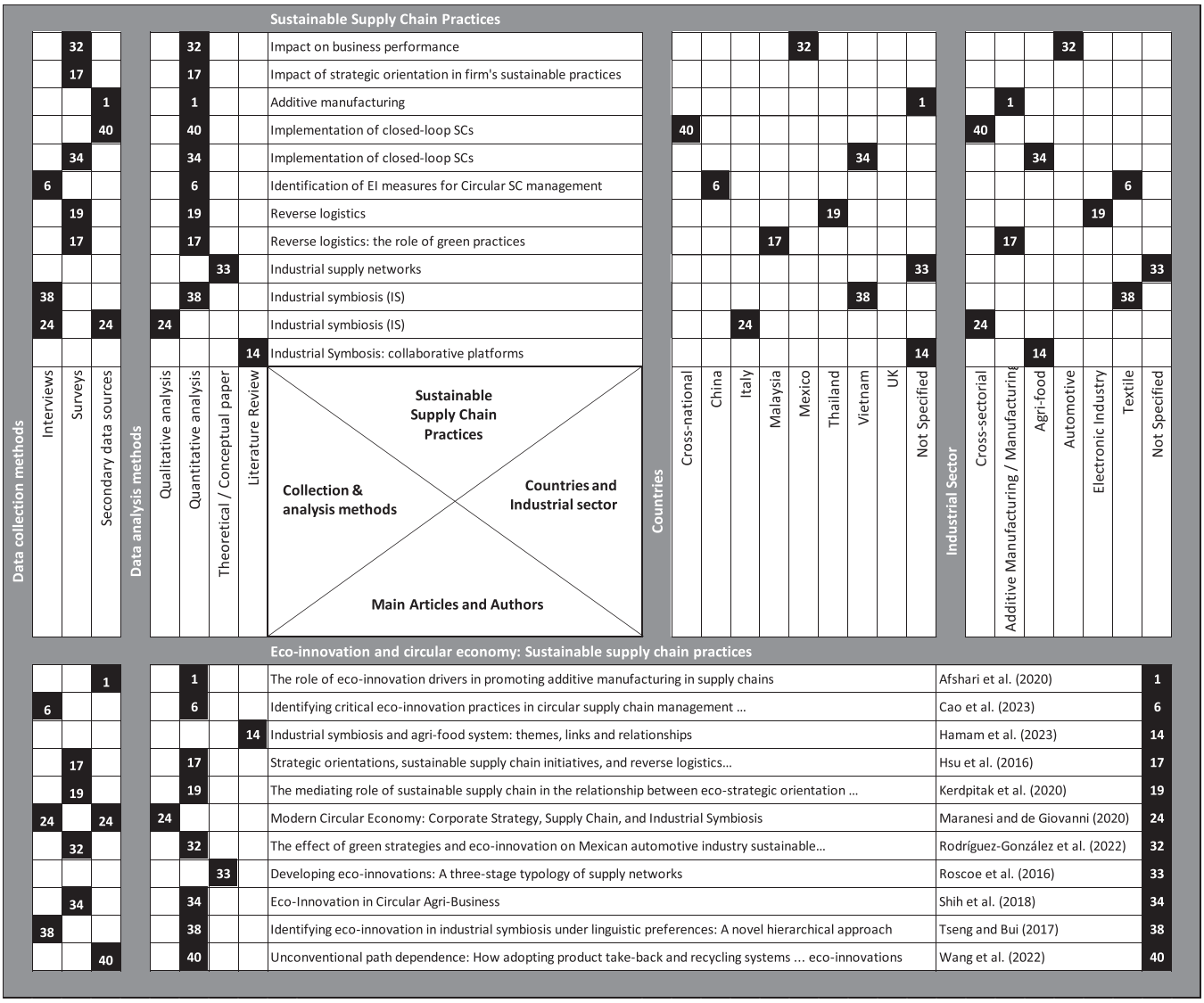

Fig. 7. Characterization of the thematic group "Eco-Innovation and Circular Economy: Sustainable Supply Chain Practices".

adopted the REALCAR project and, in turn, exerted pressure on other downstream SC actors, such as scrap dealers (Ramkumar, 2020). Clearly, the implementation of EIs across the SC can have a domino effect.

The role of consumers in shaping demand for EI cannot be overlooked, whether they are end customers or clients across the SC (Viale et al., 2022). To ensure consumer adoption, firms, especially through purchasing agents, need to focus on understanding end customers' demands, expectations and willingness to purchase EIs (Viale et al., 2022). As such, consumer education is crucial for the acceptance of eco-innovative practices, as it can encourage changes in purchasing habits (Dewick and Foster, 2018). Besides, consumer perception of the increased value associated with eco-innovative products influences their purchasing decisions, which can be reinforced by the information flow throughout the SC (do Canto et al., 2021). Partnering with retailers ensures effective communication with customers (do Canto et al., 2021), providing reliable information on the environmental quality of goods, which in crucial for driving the adoption of EIs. In the case of REALCAR, it was a customer requirement from JLR that pushed suppliers to adopt the EI (Ramkumar, 2020). The type of ownership can also influence collaborations among SC members, with Brazilian family-run companies being more receptive to collaboration with different SC members (do Canto et al., 2021).

Ocicka et al. (2022) compared different types of external collaborations, including both customers and suppliers (upstream-downstream external collaboration), only suppliers (upstream external collaboration), or only customers (downstream external collaboration). They concluded that companies that cooperate with both customers and suppliers are more likely to develop EIs than those who only cooperate with only one group of partners (Ocicka et al., 2022). However, collaboration (with suppliers) at an early stage of the SC results in a higher degree of eco-innovation than when it occurs at a later stage (with customers) (Ocicka et al., 2022). Among the various factors that influence EI development across firms in the SC, innovation alliances with suppliers play an important role, as knowledge spillovers and technology gaps significantly impact the EI levels of suppliers (Lin et al., 2020).

In addition to inter-organizational relationships, EI within firms can also be fostered by intra-organizational factors (Viale et al., 2022). First, promoting employees' access to knowledge regarding EIs is crucial for promoting the development of new products (Giacomarra et al., 2020). Secondly, Viale et al. (2022) highlight the key role of purchasing agents in driving EI. As these agents are usually responsible for identifying, evaluating and selecting the appropriate suppliers, they also play a key role in the EI process, especially when their personal values and intrinsic motivations are aligned with sustainability (Viale et al., 2022). In that

way, they are more receptive to suppliers' EI suggestions, also verifying suppliers' compliance to environmental certifications, namely ISO 14001, which adds value during the EI process (Viale et al., 2022). Many EIs also originate from the individual initiatives of purchasing agents who personally recognize the importance of EI and seek to offer their customers more sustainable options (Viale et al., 2022). Consequently, purchasing agents must select reliable suppliers who can provide support through knowledge and resource exchange and to act proactively by suggesting eco-innovate solutions (Viale et al., 2022). To guide purchasing agents, it is crucial to provide indicators related to sustainable procurement (Viale et al., 2022). One criterion can be the ecological approach to the development of innovations (Ocicka et al., 2022). In that way, when suppliers do not meet the expected standards in terms of environmental protection, they are either rejected or asked to make adjustments (Lin et al., 2020).

Given that managerial orientation is an important driver for the adoption of EIs, managers should share drivers and indicators for EI adoption throughout the SC and select partners with similar sustainability orientations (do Canto et al., 2021). Besides managers, purchasing agents also play a key role in establishing close relationships with SC partners and promoting the implementation of EI practices across their organizations (Viale et al., 2022).

Several patterns emerge within the thematic area. First, collaboration among SC actors – suppliers, customers and sub-suppliers – is central to driving EI. If collaboration is particularly effective in addressing complex and uncertain SC environments, it is crucial to foster partnerships that enable resource-sharing, knowledge exchange and risk mitigation that enhance EI adoption (e.g. Ocicka et al., 2022; do Canto et al., 2021; Giacomarra et al., 2020). Second, for collaboration to take place, focal firms act as central orchestrators in the SC, leveraging their position to facilitate EI adoption through incentives, knowledge hubs and coercive pressures when necessary (e.g. Mylan et al., 2015; Ramkumar, 2020; Viale et al., 2022). Third, upstream supplier collaboration is pivotal in initiating and accelerating EI processes, particularly during the early stages of product or process development. However, for this collaboration to take place, the flow of information and knowledge within inter-organizational networks needs to be nurtured to foster innovation co-creation, enabling firms to address sustainability challenges collaboratively and to mitigate the lack of alignment among SC members (e.g. Mylan et al., 2015; do Canto et al., 2021).

Fourth, if collaboration is to succeed, intra-organizational factors, particularly the role of purchasing agents, are critical for selecting and collaborating with environmentally compliant suppliers. Purchasing agents with personal sustainability values often act as champions for EI, proactively identifying opportunities and ensuring supplier alignment (Viale et al., 2022). Fifth, compliance with regulatory frameworks incentivizes innovation but also adds pressure for early-stage collaboration and supplier engagement (e.g. Arfaoui, 2018). Sixth, it is important to be sustainable oriented, as aligning the sustainability orientations of SC actors enhances collaboration and fosters a shared commitment to EI goals, which can help firms to achieve better environmental outcomes (e.g. Ocicka et al., 2022; Lin et al., 2020; Viale et al., 2022). Finally, transparency in SC operations, coupled with effective communication with customers, builds trust and reinforces consumer adoption of eco-innovative products (e.g. Ocicka et al., 2022; Viale et al., 2022).

These patterns emphasize the interconnectedness of SC actors, the strategic importance of collaboration and the roles of both organizational and consumer dynamics in fostering eco-innovation.

4.3. The importance of partnerships and institutional pressures in the SC ecosystem

To present the nine articles included in this thematic group, we use the X-matrix (Figure 6), following the same structure of previous groups. Figure 6 reveals that there is a predominance of quantitative studies using surveys, suggesting a focus on analyzing the impact of partnerships and institutional pressures within the SC ecosystem.

Shifting from the traditional perspective of analyzing interrelationships among SC partners, this review highlights the paramount importance of the SC ecosystem in successfully triggering EIs (Cassetta et al., 2023; Paletto et al., 2021). Quadruple helix partnerships involving public institutions (governments), universities, industry and civil society can contribute to the effectiveness of EIs by promoting knowledge and expertise exchange, as well as access to complementary resources and competences (Cassetta et al., 2023; do Canto et al., 2021). The context in which businesses operate have an important impact on the EI process, influencing how innovation occurs, the willingness to take risks and the availability of having financial funding for developing and bringing EIs to market (Paletto et al., 2021). Hence, partnerships with these actors can reduce uncertainty, impact business performance and increase a firm's competitive advantage (Cassetta et al., 2023). Indeed, collaborations have a positive impact on business performance, resulting in a high probability of increased turnover when compared to firms that are not involved in stable collaborations (Cassetta et al., 2023). Cassetta et al. (2023) demonstrated that the relationship between EI and business performance is moderated by both SC partners and quadruple helix actors. Embedded relationships between the focal firm and its suppliers helps overcome competence lock-in, playing a crucial role in implementing EIs in the SC (Cassetta et al., 2023). Moreover, institutional actors, namely universities and governments, are perceived as playing a crucial role in the SC ecosystem, influencing its move towards EI. First, governments or other responsible local or regional authorities, can foster EI across the SC by providing financial incentives, subsidies (Cassetta et al., 2023; Li et al., 2023; Peng and Lin, 2022), as well as administrative, legal and political support (Crișan et al., 2021). This type support is especially relevant in least developed regions (Crișan et al., 2021). Incentives can be offered for firms to acquire a certain type of equipment or technology, driving companies in a specific sector to adopt the same behavior (Crișan et al., 2021). Government subsidies, acting as a form of external support, aim to lower costs, encourage SC integration and they also play a role in promoting circular SCM by encouraging firms' EI (Li et al., 2023). Hence, these types of subsidies have been found to have a positive association with EI, with the latter serving as a mediator in the relationship between government subsidies and circular SCM adoption (Li et al., 2023). In the electric vehicle (EV) industry, the societal pressure to reduce carbon emissions has led governments to provide subsidies in order to stimulate EI, by offering technology investments, including a percentage of R&D cost subsidies (Peng and Lin, 2022). The ultimate goal is to expand the scale of these new products, as government subsidy policies can have a spillover effect for technology followers in a specific industry, meaning that followers in one industry will subsequently follow the leaders under the subsidy policy (Peng and Lin, 2022). Moreover, government subsidies enhance the EI level of technology leaders, acting as incentives to improve EI levels (Peng and Lin, 2022). Regardless of the SC structure and the type of subsidy offered, the technology gap remains between followers and leaders, with the EI level of the technology leader always being higher than that of the followers (Peng and Lin, 2022). So, it is crucial for governments to promote cooperation and exchange activities to improve the EI level, reducing information asymmetries across the SC (Peng and Lin, 2022). Furthermore, government subsidies can influence consumers' decision-making process, encouraging the purchase of eco-innovative products, such as EVs, by reducing taxes to offset the high cost of research and development in this market, promoting its expansion (Peng and Lin, 2022). Policymakers play a role in promoting the use of innovative technologies at both consumer and firm level, for example, by enacting specific legislation to close industrial loops (Bag et al., 2022).

Both national and transnational governmental bodies can promote regulatory pressures and policies that ultimately influence the development of EI (Arfaoui, 2018), involving the entire SC (Cassetta et al., 2023). Arfaoui (2018) shows that there is a positive correlation between environmental regulation and EI, even though it depends on firm size, as

regulatory pressures can have a negative impact on smaller firms due to resource constraints. The European regulation REACH, for example, which became effective in 2007, aims to encourage EI by supporting internal R&D activities, as well as promoting the use of external sources of information through collaborations and partnerships to meet consumer demands (Arfaoui, 2018). Involving various partners and actors enhances a firm's capacity for eco-innovation, especially when barriers to innovation, cost and market access are addressed (Arfaoui, 2018). REACH aims to protect human health and the environment, while promoting competitiveness and innovation in this industry (ECHA, 2023). Unlike previous regulations, it provides a comprehensive set of environmental policy instruments to encourage EIs, requiring firms to provide information and seek alternative R&D methods to develop safety substances (Arfaoui, 2018). This heavy regulation on the chemical industry is justified by its widely known negative impact on the environment and its impact on multiple industries (Arfaoui, 2018). However, policymakers should consider promoting similar regulation strategies in other industrial sectors to enhance communication and coordination throughout the SC, which will push EI (Arfaoui, 2018).

Other institutional pressures arising from government agencies and regulatory mechanisms can have a positive impact on the development and implementation of EI, influencing SC collaboration, particularly with suppliers (Bag et al., 2022; Hofman et al., 2020). For example, normative pressures from local communities and civil society groups are the most significant drivers for Chinese firms to engage in collaboration with suppliers to develop EIs (Hofman et al., 2020).

Paletto et al. (2021) also reflect upon the vital role that universities and research institutes play in promoting knowledge transfer and information exchange, aiding in the identification process of novel opportunities and investing in knowledge creation, thus increasing the diffusion of EI. Therefore, universities can provide knowledge and expertise for EI, leading to competitive advantage (Cassetta et al., 2023), In turn, this enhances the efficiency of SCs while reducing their negative environmental impacts (Paletto et al., 2021).

While process-oriented EIs benefit from collaborations with stakeholders of all single helices, the success of product-oriented EIs is mainly moderated by the interactions with civil society, as they represent a large portion of final consumers (Cassetta et al., 2023). Civil society plays an important role in fostering the co-creation and co-production of EIs by raising firm's awareness of environmental problems, the need for more sustainable products and the impact of those innovations on the environment (Cassetta et al., 2023). Therefore, collaborations with civil society, namely with non-profit organizations (NGOs), enable companies to access external expert knowledge providers, mediators and supporters of more environmentally-friendly businesses, providing firms with foundations for developing EI (Cassetta et al., 2023; do Canto et al., 2021).

Several patterns emerge from this thematic area. The first is the central role of the SC ecosystem, as EI success is deeply influenced by the broader SC ecosystem rather than individual actors (Cassetta et al., 2023; Paletto et al., 2021). The second pattern is the importance of quadruple helix partnerships as catalysts for EI involving collaboration among governments, academia, businesses and civil society to reduce uncertainties, foster innovation and improve business performance (Cassetta et al., 2023; do Canto et al., 2021). A third pattern is the key role of regulatory and normative pressures shape EI implementation and push SC eco-innovations, as firms are driven to innovate through stricter standards and incentives for compliance, to foster SC collaboration, particularly with suppliers and to align innovation efforts with sustainability goals to reduce environmental impact (e.g. Cassetta et al., 2023; Crișan et al., 2021; Li et al., 2023; Peng and Lin, 2022).

On one hand, process-oriented EIs benefit most from stakeholder collaboration across all helices, reflecting a need for diverse input and systemic integration. On the other hand, product-oriented EIs are predominantly influenced by consumer-facing entities like civil society, aligning with market demands and environmental awareness. This indicates that there is a differentiated pattern regarding the impact of process vs. product-oriented EIs. This has implications for the importance of governments and public institutions as they play a vital role in fostering EI through funding, regulatory frameworks and knowledge transfer bridging the gap between technology leaders and followers by promoting collaborative innovation and reducing information asymmetries (Peng and Lin, 2022). The fifth pattern is the role of civil society as a co-creator of EI, as civil society fosters co-production of innovations by highlighting environmental issues and promoting demand for sustainable products underpinning product-oriented innovations aligned with consumer expectations. Finally, circular SCM as a target outcome emerges as the sixth pattern. If government policies and incentives aim to integrate EI with circular SCM they need for collaborative innovation across the SC ecosystem by promoting recycling, waste reduction and resource efficiency (Bag et al., 2022; Peng and Lin, 2022).

These patterns reflect a dynamic interplay between partnerships, institutional pressures and contextual factors, underscoring the importance of a holistic approach to driving eco-innovation within the SC ecosystem. However, resource limitations, particularly for smaller firms, hinder their ability to meet regulatory pressures or participate in collaborations effectively.

4.4. Eco-innovation and circular economy: sustainable supply chain practices

The fourth thematic group, comprising 11 articles, is represented by the X-matrix shown in Figure 7, centering upon the theme of sustainable supply chain practices. Similar to the previous thematic group, this group also shows a predominance of quantitative studies, as illustrated in Figure 7, which suggests a focus on collecting numerical data to explore and assess sustainable practices within SCs.

The development of EI can confer a competitive advantage in the global market and lead to substantial improvements in sustainable and financial performance (Rodríguez-González et al., 2022). To sustain their SC initiatives effectively, companies must prioritize the establishment of eco-reputation and eco-innovation strategic orientations first (Hsu et al., 2016). This demands that managers possess the knowledge and ability to implement appropriate EI-based green strategies that strengthen SC sustainability. For instance, Afshari et al. (2020) investigated additive manufacturing as a potentially transformative innovation, noting its positive impact on sustainability due to reduced material usage and its potential to enhance financial performance.

The concept of CE has gained prominence with the growing emphasis on sustainable development (Wang et al., 2022). Companies can advance their EI practices by adopting CE principles, such as closing loops of waste material through "product take-back and recycling" (Wang et al., 2022). Implementing a closed-loop supply chain is especially important in circular agri-businesses, as it significantly drives EI in these firms when combined with other EI attributes, such as environmental technologies and green innovation processes, that highlight knowledge sharing among the firm's partners and employees, as well as cooperation with suppliers (Shih et al., 2018).

The literature identifies five essential factors of CE in SCs, encompassing economic, environmental, operational, organizational and resilience aspects (Cao et al., 2022). Reverse logistics and industrial symbiosis emerge as the primary practices of CE in SCs. Reverse logistics involves the recovery, reassembly and recycling of products, offering potential revenue through secondary channels (Kerdpitak et al., 2020). Besides, the implementation of different green practices, namely green manufacturing and green packaging, are shown to increase the performance of firm's reverse logistics operations (Hsu et al., 2016). As such, managers should view reverse logistics not merely as a cost center but as a strategic SC activity that generates value (Kerdpitak et al., 2020).

Establishing industrial supply networks is fundamental for knowledge transfer, potentially enhancing focal firms' sustainability performance and influencing the development of incremental EIs through

strong ties and radical EIs through weak ties with suppliers (Roscoe et al., 2016). Industrial Symbiosis (IS) serves as a practical example of both EI and CE. In this collaborative model, stakeholders and communities improve their resource efficiency by sharing waste management practices (Tseng and Bui, 2017), IS networking reduces waste disposal and material requirements by promoting the reuse of waste and scraps from other industries (Maranesi and De Giovanni, 2020). Collaborative platforms must be established to facilitate the exchange of by-products between companies, effectively integrating industrial scraps and waste into various supply chains stages, including transportation, raw-material, production (Hamam et al., 2023).

Within this thematic several patterns emerge. First, the integration of eco-innovation and circular economy principles as their practices drive sustainability across SCs by promoting recycling, reuse and waste reduction. However, for this integration to take place, companies must prioritize building an eco-reputation and aligning their strategies with green goals to sustain their SC initiatives effectively to strengthen SC sustainability and improve financial performance (e.g. Afshari et al., 2020; Hsu et al., 2016). Second, reverse logistics is a strategic driver for CE and EI, as it encompasses product recovery, reassembly and recycling, core CE practices that transform waste into revenue-generating opportunities fostering long-term economic and environmental sustainability (Shih et al., 2018; Wang et al., 2022). Third, a holistic approach to CE adoption is an important pattern as effective CE implementation requires balancing five dimensions – economic, environmental, operational, organizational and resilience. For that firms must adopt a comprehensive view, integrating green technologies, reverse logistics and industrial symbiosis into their SC practices (Cao et al., 2023; Kerdpitak et al., 2020). Fourth, it is possible to achieve competitive advantage through sustainability as EI and CE practices not only address environmental challenges but also confer a significant competitive advantage in global markets, especially when firms align strategically CE and EI with their SC operations to improve their financial performance and market position (e.g. Maranesi and De Giovanni, 2020; Roscoe et al., 2016; Tseng and Bui, 2017).

These patterns emphasize the symbiotic relationship between EI and CE, highlighting collaboration, operational efficiency and strategic alignment as key drivers for sustainable supply chain practices.

5. Conclusions

The implementation of eco-innovative practices in the supply chain poses firms several regulatory, economic, financial, strategic and technological multifaceted challenges. However, intra-organizational factors affect the dynamics within firms, such as: the role of personal values and intrinsic motivations of purchasing agents; and the alignment with sustainability goals, which shape eco-innovative practices across the SC. As such, if EI practices are to succeed, supplier collaboration is mandatory so that supplier engagement take place through the provision of best practices, external knowledge and the implementation of sustainable practices. Setting drivers and indicators of EI adoption are important managerial practices for ensuring alignment of sustainability objectives across the SC and guiding purchasing agents to select partners with similar environmental orientations.

The role of inter-organizational relationships is crucial for developing and successfully implementing Eis throughout the SC. Effective EI involves complex networks among various SC actors (suppliers, sub-suppliers, customers) to enable information and knowledge exchange, enhance join capabilities and resource sharing and mitigate risk and cost, facilitating resource allocation, reducing information asymmetry, facilitating regulatory compliance and alignment with other players across the SC. Finally, early-stage collaborations with suppliers have particularly significant impact for driving EI and overcoming uncertainties associated with sustainable practices.

Focal firms have the responsibility to coordinate relationships across the SC, ensuring the successful implementation of EIs by mobilizing support from SC partners and managing internal stakeholders, including employees, purchasing agents and managers. External collaboration with supply chain partners, especially with suppliers and/or customers, is crucial for the development of successful EI. However, firms should go beyond traditional SC partnerships and engage in partnerships with universities, public research centers, government and civil society. Collaborations with actors from different spheres, including quadruple helix partnerships, enhance the knowledge and resources available to businesses, facilitating knowledge sharing, business model innovation and the EI process.

Suppliers need to adapt their processes and engage in collaborative relationships with focal firms and other stakeholders to support eco-innovation. Balancing the costs of adopting new technologies and complying with environmental regulations are major challenges. Suppliers also need to ensure effective engagement in knowledge-sharing activities to drive sustainable practices. All players in the SC ecosystem face overarching challenges, including effective coordination, resource and capability development and fostering a culture of sustainability. Addressing these challenges requires a concerted effort across the entire supply chain, with a focus on communication, collaboration and strategic planning.

Technological barriers require investments in facilities and infrastructure that many companies struggle to implement effectively. However, technology is one of the best solutions for a successful transition to sustainable practices by allowing the assessment and monitoring of environmental new processes. Moreover, the implementation of complementary technological solutions can help SC managers track eco-innovation practices, such as gas emissions, on a daily basis. Thus, managerial orientation is fundamental for the development and implementation of EI across the SC. This is particularly relevant for understanding the drivers and practices adopted by companies to implement EI in their SCs, aiming to achieve and enhance sustainability. As such, effective public policy is crucial, which demands the provision of incentives, subsidies and regulatory support to encourage firms to adopt sustainable practices and industry-wide standards. Moreover, promoting cross-sector collaboration and providing the necessary infrastructure are essential steps for fostering symbiosis and closed-loop systems.

The development of EI can provide firms a competitive advantage in navigating the increasing uncertainty and complexity of the global market while contributing to improved sustainable and financial performance. Companies should prioritize the development of their eco-reputation and eco-innovation strategic orientations to sustain their supply chain initiatives. The adoption of a circular economy approach, with practices such as reverse logistics and industrial symbiosis networking, drives EI in SCs through multi-stakeholder collaboration. This highlights the interconnectedness and collaborative nature needed to achieve EC in SCs. Achieving a circular economy is only possible if stakeholders participate in collaborative networks, manage product life cycle, enhance resource efficiency and encourage closed-loop systems.

In sum, given the crucial role of interrelationships among multiple stakeholders in driving EI throughout the SC, one can say that *if focal firms want to go fast, they may go alone; but if they want to go far, they must go together*, i.e., long-term success and sustainability require collaborations and partnerships with SC partners and actors from different quadrants, involving governments, universities, industry and society. To better illustrate the insights derived from this SLR, Figure 8 synthesizes the main challenges found, taking into account the different stakeholders and perspectives of the supply chain, ecosystem, industry and public policy.

As usual, despite its importance, this article has some limitations. Firstly, although SRLs provide a very reach ground for the emergence of a diverse group of topics from the content analyzed, during the SLR a broad perspective was taken into account, as terms such as partnerships, collaboration, inter-organizational relationships, networks, among others, were used to refer some very specific types of relationships, and sometimes loosely, without any single definition. As such, we used the

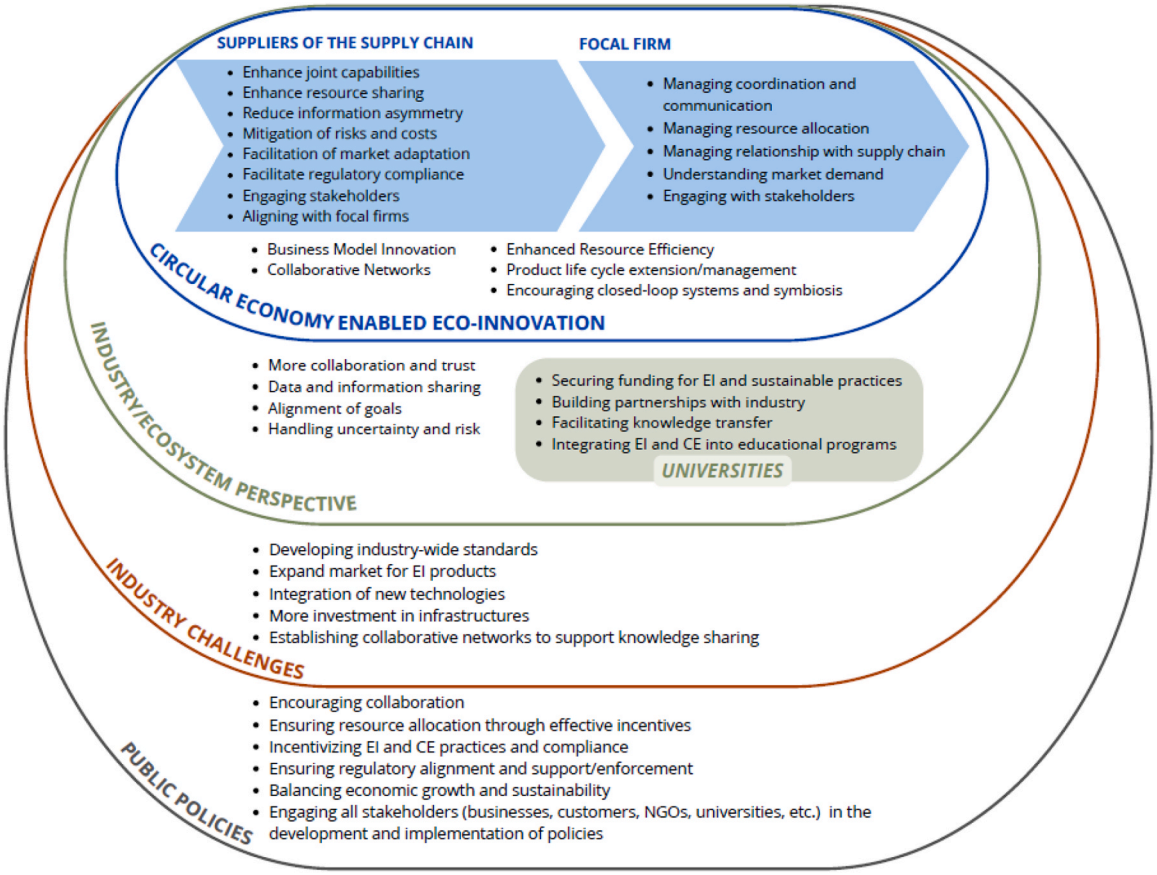

Fig. 8. Illustrative summary of key findings of this SLR.

terms that were used by the authors. Secondly, this SLR is based on the thematic content analyzed, not following streamlined protocols that can be more easily implemented in more mature scientific fields. Another limitation is related to the fact that some of the reviewed articles are included in more than one thematic group (e.g., Arfaoui, 2018; Bag et al., 2022; do Canto et al., 2021; Li et al., 2023). This overlap suggests the interdisciplinary nature of some articles, that address multiple aspects of the topic being researched. Additionally, the search for relevant studies was conducted using only the Scopus database. While there is some overlap between Scopus and Web of Science, this still represents a limitation, as it may have excluded studies indexed exclusively in other databases.

6. Future research agenda

The primary objective of a SLR is to identify research gaps and suggest future research directions (Paul and Criado, 2020). Building on our review findings, which emphasize the importance of multi-stakeholder collaborations and partnerships among supply chain partners and Quadruple Helix actors in driving EI, future research needs to address the role of technologies in stimulating EIs by facilitating information and knowledge transfer across the SC. Additionally, the use of technologies, such as blockchain and big data, can help companies mitigate risks in the SC and face navigate uncertainties, making them potential areas of inquiry for future studies.

Considering that the implementation and development of EI depends on multiple stakeholders interacting with the focal firm, future studies could adopt the stakeholder theory (Freeman, 1984) to analyze the role of both internal and external stakeholders in shaping a firm's commitment to EI. Further investigation can also explore the individual characteristics of internal stakeholders, namely managers and leaders in different departments, to understand their influence on driving EI within the organization and across its SC. Also, exploring ways to align and engage purchasing agents with sustainability concerns to drive EI would be of added value. Given that the level of collaboration involvement may vary across different socio-economic contexts, cross-country studies should be conducted.

Gaining a deeper understanding of barriers to the development and implementation of EI in SCs is crucial for designing strategic actions at the management level and guiding concrete operational activities. Therefore, future research could employ qualitative methodologies, such as interviews with expert panel groups from various types of industries, to analyze and prioritize challenges in different sectors. This approach can highlight potential practices for cross-sector replication, while considering regional variations. This would facilitate the development of EI indicators tailored to specific sectors. Hence, cross-country comparisons and comparative studies are needed to examine different industries and geographical contexts.

As the lack of collaboration among SC members is a significant barrier to achieving sustainability, it would be important to investigate how using economic incentives, coordination mechanisms and developing eco-performance standards could foster collaboration and align social capital across players in the SC. Misalignment of social capital, lack of shared sustainability orientation and transaction-oriented relationships are highlighted as issues that hinder effective collaboration.

To provide a comprehensive view of the role of inter- and intra-organizational relationships in driving eco-innovation within SCs, it would be important to assess the most effective ways for leveraging internal and external knowledge sources and what are the advantages and disadvantages of different types of collaborations and how effective they are in the different contexts.

Building on the findings of one study in our review that highlighted

heavy regulation driving EI in the chemical industry, it would be worthwhile to explore the role of legislation in other industries to assess whether it hinders or promotes EI across the SC. Furthermore, investigating co-creation as a method for driving EI in the SC and its role in fostering more circular supply chains would be valuable. Additionally, studies that combine open innovation and co-creation could provide further insights. However, it is important to consider intellectual property rights and knowledge transfer, as they may hinder EI practices.

It would be of added value the analysis of how business ecosystems influence the players of the ecosystem. As such, investigating the interplay between government, society and industry could provide a broader perspective of the interactions among actors of the ecosystem, namely from a comparative perspective involving intersectoral ecosystems. Another important research avenue that seems absent in the field is how digitalization can underpin sustainable control systems and EI in the SC.

Finally, examining market and social challenges is crucial to understanding consumer decision-making processes regarding eco-innovative products. Studies are needed to explore how purchasing behavior can be influenced and the drivers that consumers face in relation to the adoption of EIs.

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Ethical Statement

Ana Inês, Andreia Diniz, and António C. Moreira declare that this paper does not involve the use of animal or human subjects. It just involves literature review and analysis of documents. We also declare that we worked with the highest standards of professional conduct including openness, fairness, honesty and integrity. This research was prepared in a reliable and trustworthy manner

CRediT authorship contribution statement

Andreia Diniz: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Ana Inês:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **António C. Moreira:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of Competing Interest

Ana Inês, Andreia Diniz, and António C. Moreira declare that they do not have any conflict of interest regarding the content or submission of this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.joitmc.2025.100472.

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