Greening the Innovation Landscape: Leveraging Open Innovation Channels for Sustainable Technology Adoption

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Abstract: Open innovation offers a great potential for accelerating sustainable technology adoption. This study presents the diverse interaction channels of open innovation and their role in facilitating the development and integration of sustainable solutions. Through an analysis of collaboration mechanisms associated with various open innovation channels in sustainable technology adoption projects, this paper offers a comprehensive framework for partnerships to strategically execute innovation strategies geared towards furthering sustainability objectives. The findings highlight the transformative potential of different open innovation interaction channels in advancing sustainability agendas. Several collaboration mechanisms support the benefits of employing the open innovation interaction channels. By categorizing and evaluating different interaction channels conducive for sustainable solutions this study explores the interplay between open innovation processes and sustainable innovation, assesses the role of different collaboration mechanisms in driving sustainable open innovation, discusses metrics to measure the effectiveness of open innovation interactions in sustainable initiatives and provides new ideas for managers to improve sustainable innovation performance.

Keywords: Open Innovation; Sustainable Open Innovation; Sustainability; Open Innovation Partnerships; Interaction Channels; Collaboration Mechanisms

1. Introduction

Open innovation (OI) and sustainability represent interconnected themes that have gained recognition within the field of innovation management. The concept of OI, characterized by engaging with external actors, is being recognized for its role in advancing sustainability-oriented innovations through the facilitation of knowledge exchange, the enhancement of creativity, and the adoption of a more inclusive stakeholder approach (Kimpimäki et al., 2022; Rauter, 2019). Empirical studies have demonstrated that the application of OI strategies can foster the development of more sustainable business models and innovation practices (Cappa et al., 2019; Franco et al., 2021). This, in turn, contributes to the enhanced performance and growth of organizations, underlining the synergistic potential between OI and sustainability efforts.

While the significance of OI and sustainability is widely acknowledged, there has been limited research on their interplay and joint impact (Cillo et al. 2019). Most studies have traditionally examined these phenomena in isolation, with only a few delving into their interconnectedness (Beck et al., 2022; Rangus et al., 2016; Slavec et al., 2019). This paper aims to bridge this gap by integrating insights from both fields to shed light on how various OI interaction channels can facilitate the achievement of sustainability objectives. There's an increasing awareness of OI's potential in tackling major societal and environmental challenges, positioning it as a catalyst for sustainable development. However, there's a need for a deeper understanding of how OI practices themselves can be rendered sustainable (Kimpimäki et al., 2022). The recent efforts to merge the concepts of openness and sustainability, such as the notion of 'sustainable open innovation' proposed by Bogers et al. (2020), remain the specific role and implications of OI interaction channels in this context underexplored. This paper seeks to shed light on the ways in which OI channels can contribute to sustainable goals within R&D oriented OI partnerships, the collaborative mechanisms that enhance the effectiveness of these channels, and the possible limitations associated with various approaches.

Considering the complex nature of our study, we employed a qualitative approach to research, as outlined by Yin (2009). Given the exploratory character of our study, our goal was to deepen the understanding of complex OI processes and their role in achieving sustainability objectives, from the viewpoint of OI partnership coordinators. Our research seeks to uncover recurring patterns and key elements, exploring the interplay between different dimensions of OI and sustainability, particularly through various forms of interaction channels. The findings of this investigation indicate that several factors facilitate OI for sustainability, such as cross-sector collaborations, knowledge sharing mechanisms and active engagement with stakeholders.

2. Open Innovation Interaction Channels Driving Sustainability

OI can be characterized as a decentralized innovation approach that involves the governance of knowledge flows across organizational lines, both inbound and outbound, for financial and non-financial gains, conforming to the

organization's commercial approach (Chesbrough et al., 2014). Comprehensive studies on OI has confirmed its significant benefits across various types of innovation (Bogers et al., 2018). However, the existing body of literature also acknowledges the presence of costs and downsides associated with OI (Dahlander et al., 2021; Stefan et al., 2022).

Within an OI ecosystem, individual actors do not operate in isolation; instead, they engage in collaborative efforts, co-creating knowledge, and continuously adapting their range of interaction channels to generate new value (Ogink et al., 2023). The growing complexity of knowledge necessitates multiple innovation partnerships and diverse interaction channels to increase the potential of addressing appropriate innovation demands (Bogers et al., 2017). Open innovation interactions encompass different inbound, outbound, and coupled processes encompass representing the diversity of functions, relations, and organizational setups (Bogers et al., 2017; Audretsch & Belitski, 2023). These interactions can take many forms, including co-creation of innovation in science-industry partnerships and user innovation, crowdsourcing, patenting and licensing, utilizing open data, among others (Beck et al., 2022) Each of interaction channels has a core purpose to establish an environment that fosters innovation success. Bogers et al. (2017) emphasize the significance of OI channels, such as platform-based systems, crowdsourcing communities, and open data, as important contexts for future research on the network level. The requirement for a specific OI interaction type depends on the industry and commercial approach (Chesbrough and Bogers, 2014). The choice of interaction channels depends on various elements, such as the nature of the partnership, and the preferences of the partners involved.

There are several types of OI interaction channels that can be used for sustainable goals (Mcphillips et al., 2024; Kimpimäki, 2022; Urbinati et al., 2022). External knowledge sourcing involves harnesses knowledge from science and non-science partners, through various means such as university-industry collaborations and inter-organizational partnerships, facilitating both knowledge sharing and acquisition (Radziwon & Bogers, 2019). These interaction type can extend beyond formal projects to include commission projects and staff exchanges, significantly impacting knowledge flow through both formal and informal channels (Hossain & Kauranen, 2016). According to Hendricks & Matthyssens, (2022), in an institutionalized business market, strategic collaborations among key market players are crucial. This study highlights the significance of intensified interactions and carefully chosen partnerships in driving sustainable innovation initiatives within such markets.

OI platforms facilitate open and distributed innovation, characterized by modularity and interoperability, but face governance issues such as intellectual property control and technology access (Gawer & Cusumano, 2014). According to (Čolić et al., 2023), collaborative platforms have the potential to enhance transformative learning beyond academia, showcasing the outcomes of transformative experiences for sustainable development. Technology transfer in OI involves mechanisms like patents and licensing, aiming to enhance innovation performance by capitalizing on knowledge assets, yet is challenged by knowledge leakages and the need for novelty in patent applications (Bogers et al., 2017). Many scholars have emphasized the importance of technology transfer in driving sustainable innovation (e.g. Fernandes et al., 2021)

User innovation, where individuals modify or create products, contributes significantly to OI by meeting unmet needs and fostering user loyalty, though organizations often underestimate its potential (Piller & West, 2014). Arancio et al. (2022) discusses the utilization of open innovation through user challenge competitions to promote sustainable development goals. Crowdsourcing, another OI interaction channel, leverages the crowd's wisdom to enhance innovation performance, requiring careful task design and participant management (Brabham, 2013). Testa et al. (2023) highlights the importance of environmentally sustainable projects in attracting funds and engaging crowd investors, emphasizing the significance of framing messages on environmental protection for crowdfunding success. Public sector partnerships in OI, involving open data from public organizations, offer new innovation opportunities but necessitate robust management and transparency (Sadiq & Indulska, 2017; Urbinati et al., 2023). Bertello et al. (2023) points out the need for exploring sustainable innovation within the realm of open data. According to Hrustek et al., (2022), the integration of open governmental and public data, along with contractual sharing, is crucial for creating sustainable value in agricultural systems.

OI interaction channels have the capacity to shape more sustainable business models and innovation practices, empowering organizations to remain competitive and aligned with the latest advancements in technology (Obradović et al., 2021). The relationship between OI and sustainability is complex and multifaceted, with implications for various industries and research areas. While the interaction channels through which open innovation promotes sustainability may vary, the evidence suggests that embracing OI practices can be instrumental in driving sustainable innovation and addressing environmental challenges (Milana & Ulrich, 2022)

As OI interaction channels serve as the infrastructure facilitating the absorption and dissemination of heterogeneous knowledge assets, the collaboration mechanisms are the orchestrated processes that govern the dynamics of interaction within these channels, ensuring the alignment of objectives, the mitigation of intellectual property risks, and the optimization of synergistic potential (Miranda et al., 2023). They refer to the processes, structures, and strategies used to coordinate and align the activities in an OI partnership. Collaboration mechanisms can include joint planning and decision-making processes, shared goals and performance metrics, division of labor and responsibilities, intellectual property agreements, and governance structures. Effective collaboration mechanisms can help to overcome challenges prevailing in some of the OI interaction channels such as misaligned incentives, conflicting priorities, and differing levels of commitment among partners.

Moreover, they can help partnerships to access new knowledge resources leading to more innovative and sustainable solutions. Reficco et al., (2018) suggest that several collaboration mechanisms positively influence innovation targeted at sustainablility, but the effectiveness of these mechanisms largely depends on the kind of partners involved. OI projects for sustainability purposes lead to increased creativity and reduced project duration. However, the potential benefits of OI projects are obstructed by the high degree of complexity that they entail. Collaboration mechanisms are mitigating those obstructions. Lappalainen et al. (2023) suggests that managing governance, control, and social relations are critical to the success of OI projects. Effective communication and knowledge flows among partners are also essential to ensure successful collaboration. Furthermore, a study by Rauter et al. (2019) uncovers the influence of diverse OI partners, including customers, universities, and broader ecosystem stakeholders like intermediaries or NGOs, on the economic and sustainability innovation performance. External actors' involvement in OI seems to be a key factor for performance. By engaging a diverse array of stakeholders, partnerships can gain access to a wealth of ideas, expertise, and resources. This multi-stakeholder engagement thus significantly contributes to overcoming the barriers associated with OI, driving forward the agenda of sustainable innovation. Kimpimäki et al., (2022) also highlight the importance of a broader stakeholder approach to sustainable innovation and emphasizes the need for a mindset shift from "inside-out" to "outside-in" to become truly sustainable. Overall, the studies suggest that effective collaboration mechanisms are essential to the success of OI projects geared towards furthering sustainability objectives.

Challenges faced in utilizing OI interactions include innovation capability, partnership expectations, and risks (Howells et al., 2012; Steinmo & Rasmussen, 2018; Radziwon & Bogers, 2019). Implementing OI for sustainable innovation presents similar challenges (Rauter et al., 2019). OI may lead to a loss of control (or perceived loss) over the innovation process, as partnerships involve collaboration with external partners and share intellectual property. Coordinating and managing a varied group of stakeholders in the sustainable context can be complex, requiring additional resources and expertise. Partnerships must carefully select partners that align with their sustainability goals and have the necessary expertise to contribute. The solutions not always can be scaled up and implemented across different operations. Measurement and assessment of the impact is also complex and multifaced. Many researchers struggle with evaluating how opening up internal innovation processes impacts innovation results and economic performance. Studies like Kratzer et al. (2017) suggest this impact might be limited, potentially leading to smaller gains in innovation over time or even negative effects, as pointed out by Greco et al. (2017). This inconsistency in findings could be because we don't yet fully understand how OI contributes to a organization's competitive edge or under what specific conditions it is most effective (Zhang et al., 2023).

3. Methods

This research focused on examining the adoption of OI interaction channels to explore their role in advancing sustainable objectives within OI partnerships. We began by identifying key attributes and roles of these channels in fostering sustainable innovation, drawing on a review of existing literature on the subject (Bogers et al., 2020). This review informed the creation of deductive codes that guided the analysis of our data. Because of the innovative and complex nature of our study, we grounded our investigation in a qualitative research methodology (Yin 2009), which allowed for a comprehensive exploration. Employing a qualitative framework was particularly pertinent for delving into the relatively underexplored domains of OI and sustainability processes (Kimpimäki et al., 2022). The exploratory angle of this study was defined by its aim and research queries, which were to enhance the comprehension of OI interaction channels and processes, along with their influence on sustainability objectives, from the individual perspectives of OI partnership managers. Theoretical

frameworks were employed not only to craft the research questions and objectives but also to outline the initial coding schema. The study was characterized by open-ended, process-focused questions.

The respondents were managers coordinating European OI partnerships, that had 7 to 11 years of experience in various OI projects and possessed significant expertise in sustainability, classifying them as elite informants. The focus was on OI partnerships engaged in R&D and technology adoption. The study involved eleven in-depth, semi-structured interviews conducted in three different countries, each lasting about 60 minutes on average. The OI partnerships were chosen using the maximum variation criterion to ensure a wide representation of the diverse OI interaction channels and the range of perceptions among respondents in varied contexts. Due to the adoption of purposive sampling, strict participation criteria were enforced (Patton 2002). Respondents were required to possess a minimum of three years' experience in managing an OI partnership. Additionally, they had been in contact with sustainability processes and presented familiarity with essential concepts and definitions pertinent to the field. These prerequisites were verified at the beginning of each interview. For the analysis of the data, MaxQDA, a software tool designed for qualitative data analysis, was used to facilitate the process.

4. Results

The most common OI interaction channels reported by respondents were sourcing of external knowledge, technology transfer, platforms and complex systems and engaging users. Utilizing open data or crowdsourcing were much less common. The effect of utilizing those channels on sustainability goals was prevalent. Despite initial hesitance among participants about how to assess the direct connection and the impact of interaction channels on sustainability, all respondents reported a beneficial influence on achieving sustainability goals.

OI interactions were perceived as a set of beneficial practices that drive the innovation processes in all areas, including sustainability. The OI partnership managers emphasized three key factors influencing sustainable outcomes in OI partnerships regardless the interaction channel in terms of collaboration mechanisms: (1) cross-sector collaborations, (2) knowledge sharing mechanisms (3) active engagement with stakeholders.

Cross-sector collaborations emerged in the study as a vital catalyst for fostering innovation and driving widespread adoption of sustainable technologies. Respondents underlined importance of combining varied expertise, which they saw as key to solving complex problems. This blending of skills not only filled technological gaps but also encouraged a culture of creative thinking. Knowledge sharing mechanisms were pointed to as playing role in leveraging collective expertise and accelerating the pace of sustainable innovation. Open communication and fair distribution of both risks and benefits, trust and clear governance were highlighted as crucial for the success of these collaborations. The use of digital tools for collaboration was another important theme. These tools were found to significantly improve the efficiency and effectiveness of projects. The results highlighted the importance of actively involving stakeholders throughout the project lifecycle. Participants from various sectors stressed the value of engaging a broad spectrum of stakeholders, including customers, suppliers, and ecosystem members, right from the early stages. This approach brought diverse perspectives into the project, making the innovations more relevant and widely accepted. Feedback loops with stakeholders were particularly noted for their role in addressing sustainability challenges effectively, allowing projects to adapt based on ongoing input.

Our study identified several metrics, used to measure the effectiveness of OI interactions in sustainable initiatives. Some implemented metrics includes: input metrics, when the resources and activities invested in OI were measured, such as the number of partners, projects, or platforms used; output metrics, connected to the results and outcomes generated from OI, such as the number of ideas, prototypes, or patents produced; as well as process metrics, measuring the efficiency and effectiveness of OI processes, such as the time and cost of innovation activities. Even though the most popular metrics for projects outside of sustainability scope is return on investment (ROI) it was not commonly used for sustainability efforts. Environmental impact metrics, including carbon footprint reduction were also rarely used, aligning the assessment with the sustainability goals of the projects.

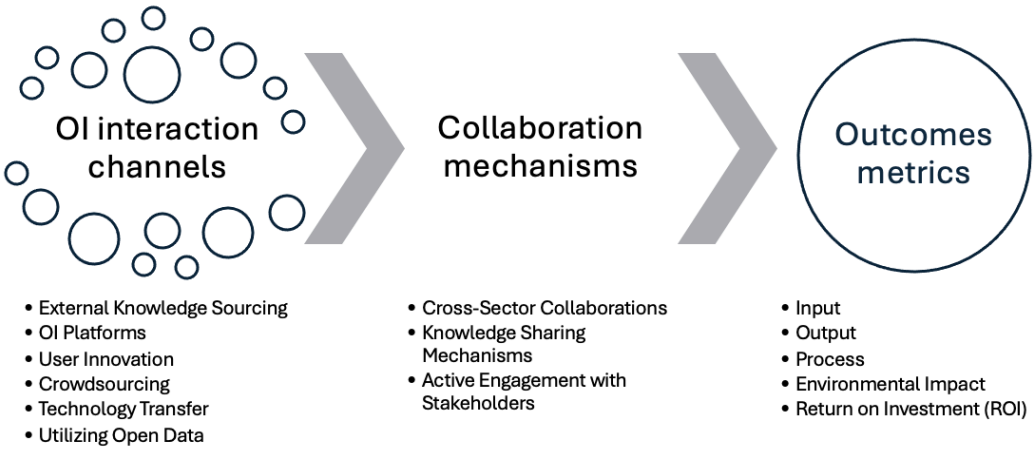

Figure 1: OI interaction channels, knowledge mechanisms and outcome metrics in OI partnerships towards sustainable objectives

Respondents pointed to several barriers that hinder the effectiveness of sustainable OI. A predominant challenge identified by participants was the misalignment of organizational goals and governance models, which often led to conflicting priorities and approaches to sustainability. Intellectual property concerns were also frequently cited, with the protection and sharing of proprietary knowledge creating tensions within collaborative frameworks. Furthermore, the complexity of coordinating across diverse stakeholder groups, each with their unique expectations and communication styles, was highlighted as a significant obstacle. These barriers, compounded by the inherent challenges of integrating sustainability into OI processes, underscore the need for indicating best practices in utilizing collaboration mechanisms targeted at OI partnerships driving sustainability projects.

5. Discussion

The research question of the role of OI interaction channels in driving the sustainability goals proved to be complex. First, the research highlighted the absence of a universally accepted framework defining sustainability within the context of OI processes. Second, the fields of OI and sustainability are characterized by a dense overlap of concepts, themes, and terminologies, leading to diverse interpretations among respondents who might use disparate terms for similar concepts. Third, different OI interactions and levels of engagement in sustainable processes produced a broad spectrum of perspectives among scholars and industry professionals (Hassan, 2022).

The respondents in this study were unable to agree on a definite description of the sustainable OI phenomenon. Nonetheless, echoing the existing literature, the results of the study indicate that sustainable OI is regarded as a process of distributed innovation that is aimed at fostering development in a manner that satisfies current requirements without hindering future generations' capacity to fulfill their own needs, aligning with the definition presented by Bogers et al. (2020). The majority of participants in this research did not mention sustainability as a priority in OI partnerships. This observation comes from the fact that OI partnerships typically do not place sustainability at the forefront of their agendas, but rather adopt sustainable practices when they coincide with, or emerge as a byproduct of, their business objectives. Even though, OI partnerships are known for having relatively modern cultures, embracing experimentation, they tend to be very cautious when it comes to financial expenditures and investments.

The existing OI literature provides frameworks of OI interaction channels (McPhillips et al.,2024). Not all of them were utilized in all of the OI partnerships. These OI channels are not easy to adopt, and sectoral preference might play a role in adoption. The extant literature frequently highlights the benefits of OI (e.g. Bogers et al., 2018). From the many advantages described in the literature, responding OI partnership managers were mostly focused on the improved process efficiency aspect, which directly contributes to reduced costs and shorter project durations. These operational improvements were mostly quantified through input and output metrics, focusing on the resources utilized and the tangible outcomes achieved.

All of the respondents declared that OI practices positively affected drive towards sustainability goals, and the unique combination of the OI interaction channels was perceived as instrumental in leveraging the effectiveness of OI, thereby facilitating significant sustainability improvement. OI managers monitor progress towards sustainability mostly by noting reductions in time and cost, which are indicative of enhanced efficiency in OI processes. Environmental impact metrics, including carbon footprint, were not used mainly due to complexity of innovation focusing of sustainability, diverse stakeholder involvement, long term impact and data availability and quality (Kemp and Pearson, 2007; Milana and Ulrich, 2022).

However, many OI partnerships do not inherently prioritize sustainability within their projects, often integrating sustainable practices only when they align with business objectives. This lack of strategic emphasis on sustainability can significantly impede progress in this area. The cautious, risk-averse culture still prevalent among many partnership members further compounds the challenge of investing in sustainable solutions. According to the data, sustainability is frequently regarded by OI managers as a context rather than a core objective, leading to a hesitancy to overhaul business models for the sake of sustainability.

6. Conclusions

Open innovation and sustainability have gained significant attention from researchers and industry professionals alike. The pressing need for collective measures to address the climate crisis underscores the growing relevance of these themes. Organizations that adopt OI are often at a competitive advantage compared to those that maintain closed innovation systems. Research and practical evidence suggest that OI contributes positively to sustainability outcomes, although with the challenge of establishing and leveraging a variety of OI interaction channels. The sustainability context imposes additional considerations on OI processes, making the adoption of OI a complex challenge with each partnership navigating its path towards sustainability in different ways (Bogers et al., 2020).

This study highlights the importance of collaboration mechanisms such as cross-sector collaborations, knowledge sharing mechanisms, and stakeholder engagement in streamlining OI processes towards sustainability. These "innovation-producing" mechanisms, as termed by Majchrzak et al. (2023), encourage the sharing of not only solutions but also essential insights into underlying problems, fostering the emergence of optimal solutions through diverse knowledge contributions within each of the OI interaction channels. Certain factors, like intellectual property issues and the complexity of governance structures, can hinder the development of sustainable OI. However, the research results suggest that successful sustainable OI emerges from the interplay of various elements (Milana & Ulrich, 2022).

The results of this paper offer valuable insights for managers in OI partnerships. A critical takeaway is the awareness of importance of different OI interaction channels. Our research demonstrates that a diverse range of OI interaction channels can markedly enhance the drive towards sustainability objectives within OI partnerships. Enhanced efficiency in OI partnerships can refine the innovation process, bringing not only financial gains but also advancing sustainability efforts. Consequently, OI partnerships that strategically embrace a variety of OI interaction channels stand a better chance of securing a competitive edge in the field of sustainability.

OI managers take on a strategic challenge to navigate the OI interaction channels within the context of sustainability dynamics. It is crucial for them to cultivate a strategic perspective of the sustainable OI process that will be deeply integrated into the fabric of the OI partnership. Such a holistic approach can facilitate the development of sustainable OI strategies that are conducive to sustainable outcomes. An essential recommendation for OI managers is to prioritize sustainability measures within the innovation process. Also, even in the face of time limitations and resource constraints, it's vital to establish sustainability objectives that also contribute to achieving financial targets, ensuring that sustainable innovation remains aligned with the overarching business strategy.

Finally, our study has uncovered that sustainable OI presents a considerable challenge for many OI managers, largely due to its complexity and unpredictability. Although OI managers are typically well-versed in OI processes, their expertise in sustainability may be lacking. It's crucial to recognize the dynamics at play, where financial gains often overshadow sustainability efforts. Consequently, sustainable OI practices may be underutilized or entirely overlooked, hindering the realization of sustainable goals. Tackling the uncertainties surrounding sustainability could empower OI managers to shift towards more structured investment risk assessments, moving away from decisions solely based on previous experiences or conventional wisdom.

While this study has provided valuable insights into the interplay between sustainability and OI interaction channels from the perspective of OI partnership managers, it's important to acknowledge its limitations, that can also pave the way for future research opportunities. The qualitative, exploratory nature of the research was designed to paint a broad picture of sustainability within the OI context as perceived by these managers. Consequently, the findings are specific to these perceptions and are not intended for broad generalizations, but rather to invite deeper examination. The study's scope did not extend to a detailed investigation of individual characteristics or the subtleties of personal experiences. Nor did it delve into the micro-level analysis concerning specific sustainability-related decisions. Essentially, while the research was centered on a meso-level analysis, it has also laid the groundwork for future studies to explore sustainability in OI at various analytical levels, thereby contributing to a more nuanced, multi-dimensional understanding of the subject.

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