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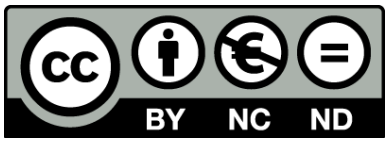
Driving Sustainable Business: The Role of Open Innovation and Digitalisation

Luis Francisco Miranda Terraza



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PhD in Business | Luis Francisco Miranda Terraza

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PhD in Business

Thesis title:

Driving Sustainable Business: The Role of Open Innovation and Digitalisation

PhD candidate:

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Advisors:

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Minna Saunila

Date:
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This dissertation, written under a cotutelle agreement between the Universitat de Barcelona, Spain, and Lappeenranta-Lahti University of Technology LUT, Finland, was jointly supervised by supervisors from both universities. It is submitted for the degree of PhD at the Universitat de Barcelona and Doctor of Science (Technology) at LUT University, to be defended with due permission for public examination and criticism at the Universitat de Barcelona, Spain.

UNIVERSITAT DE BARCELONA

LUT University

Abstract

Luis Francisco Miranda Terraza
Driving Sustainable Business: The Role of Open Innovation and Digitalisation

Sustainability, the most pressing challenge facing society today, is reshaping the relationship between companies and society. While companies have long been recognised as major contributors to environmental degradation, achieving sustainability is impossible without them reducing their environmental impact and adopting proactive strategies to protect the environment, all the while remaining profitable to meet their economic needs. To effectively address this critical goal, the factors that can strengthen business sustainability must be explored. To this end, this dissertation, contributing to the literature on corporate sustainability, examined the role of both digitalisation and open innovation in driving sustainability from a business perspective. Digitalisation has emerged as a key determinant of societal dynamics, and sustainability demands system-level approaches that extend beyond the boundaries of individual firms. The dissertation, which includes three interconnected publications, employed a combination of conceptual analysis, systematic literature review, and empirical research. The first publication conceptually examined how digital technologies facilitate environmental innovation through mechanisms such as crowdsourcing, customer co-development, and R&D alliances. Digital tools were found to enhance open collaboration by integrating external knowledge to foster environmental innovation. The second publication, by conducting a systematic literature review of 35 scientific publications to explore the relationship between open innovation and sustainability-oriented innovation, posits an integrative conceptual framework, identifying the key mechanisms, partners, enablers, and barriers in the collaboration for sustainability. Empirically investigating the relationship between business digitalisation and economic and environmental sustainability in Finnish micro, small, and medium-sized enterprises, the third publication emphasises the mediating role of environmental sustainability and the moderating role of company size. This quantitative study indicates that, while digitalisation alone does not directly improve economic sustainability, it enhances environmental sustainability, which subsequently improves economic performance. Digitalisation's benefits were also found to be more pronounced in larger companies. Overall, this dissertation advances the theoretical and practical understanding of how open innovation and digital technologies drive sustainability in businesses, contributing to the fields of corporate sustainability, innovation management, and information systems.

Keywords: sustainable business; digitalisation; environmental sustainability; sustainability-oriented innovation

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Luis Francisco Miranda Terraza
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This thesis is dedicated to my parents, Carmenza Terraza and Francisco Miranda, for their love and unconditional support.

Contents

List of publications

This dissertation is based on the following papers:

I. Miranda, L. F., Pertuz, V., Cázares, C. C., & Saunila, M. (2021). Open collaboration and digital technologies in the context of environmental innovations. In J. Marques (Ed.), *Business with a conscience: A research companion* (pp. 263-275). Routledge. https://doi.org/10.4324/9781003139461

II. Miranda, L. F., Cruz-Cázares, C., & Saunila, M. (2023). Towards a comprehensive framework to analyse the benefits of openness for sustainability-oriented innovation: A systematic literature review. *Sustainable Development, 31*(6), 4019–4038. https://doi.org/10.1002/sd.2581

III. Miranda, L. F., Saunila, M., Cruz-Cázares, C., & Ukko, J. (2024). Business digitalisation as a driver of environmental and economic sustainability in micro, small, and medium-sized enterprises. *Sustainable Development*. https://doi.org/10.1002/sd.3084

Author's contribution

Luis Francisco Miranda Terraza was the principal author and investigator of papers I, II, and III. In all three publications, he served as both the first and corresponding author. For publication I, he established the conceptual relationships and summarised the literature. In publication II, he developed the protocol for the systematic literature review, summarised the publications, and structured the integrative conceptual framework. In publication III, he developed the theoretical background, conducted data analysis, and performed validity and reliability assessments.

Abbreviations

BDA	Big data analytics
CMB	Common method bias
CB-SEM	Covariance-based structural equation modelling
HIS	High-speed infrastructure
HTMT	Heterotrait-monotrait ratio
ICT	Information and communication technology
IoT	Internet of things
MSMEs	Micro, small, and medium enterprises
OI	Open innovation
PLS-SEM	Partial least squares structural equation modelling
RBV	Resource-based view
RQ	Research question
SEM	Structural equation modelling
SLR	Systematic literature review
SOI	Sustainability-oriented innovation
VIF	Variance inflation factor

1 Introduction

1.1 Background and motivation

As firms' actions majorly contribute to environmental degradation, they have a significant responsibility to achieve sustainability (George et al., 2022) by aligning their strategies to positively impact the environment. Sustainability is thus central to the strategic direction of many firms worldwide. It is, perhaps, the greatest challenge firms face today from political, economic, and social perspectives (George et al., 2022).

Although many companies have stopped offering purely reactive responses to environmental and social issues and started engaging in proactive approaches that aim to address sustainability more strategically (Whiteman et al., 2013), the accelerated depletion of natural resources, the substantial consumption of energy and fuel, the emission of greenhouse gases, and the wastage of raw materials have raised growing concerns about the poor sustainability behaviour of companies (Schaltegger et al., 2022).

This situation has driven the recent calls to address the factors that can enable more sustainable outcomes across manufacturing firms and sectors (Baah et al., 2021). Understanding the drivers that allow businesses to improve their sustainability practices is an even more urgent task: while corporate sustainability can act as a source of sustainable competitive advantage for companies, it could also undermine society's sustainability (Barnett et al., 2022). In this context, this dissertation examined two significant drivers and megatrends of sustainability in the business world: open innovation and digitalisation.

In the business context, the understanding of sustainability—"a firm's set of programs for achieving environmental integrity, social equity, and economic prosperity" (Barnett et al., 2022, p. 4)—is based on the premise that failing to adopt sustainable business strategies will cause significant environmental degradation (George et al., 2022).

Apart from sustainability, another megatrend has emerged, driven by the rapid advancement and widespread adoption of digital technologies across several domains of life: digitalisation (Seele & Lock, 2017). Having prompted a significant global transition, digitalisation is believed to have the potential to enhance sustainability (Seele & Lock, 2017), though this remains a subject of debate in the business context, as there exists uncertainty about whether and how increased digitalisation necessarily leads to greater engagement in sustainable practices (Bendig et al., 2023) and improved business outcomes (Li et al., 2020).

Due to the inherent complexity of sustainability issues (Porter & Birdi, 2018), effectively addressing these challenges requires companies to collaborate with external partners to create innovative and practical sustainable solutions. Known as open innovation, this

strategy involves intentionally bringing together insights from various contributors to foster and leverage new innovations (Ahn et al., 2019).

While companies can leverage open innovation to acquire the necessary knowledge for developing sustainable solutions in the form of new or improved products, processes, or business models (Kennedy et al., 2017), and collaboration with external partners increases the likelihood of creating successful market innovations (Melander, 2017), only a few studies have identified and synthesised the mechanisms involved in open innovation initiatives that specifically target sustainability.

By integrating insights from corporate sustainability, innovation management, and information systems, this dissertation examined sustainability at the firm level, emphasising the collaborative aspects of organisations and the critical role of digitalisation in enhancing the environmental sustainability of companies of different sizes. Corporate sustainability, according the business and management literature, examines a firm's responses to a broad spectrum of social and environmental issues (Linnenluecke & Griffiths, 2013). Innovation management is concerned with the creation of new offerings. It addresses functional and technological risks and involves strategic resource deployment (Kahn, 2022). Lastly, the information systems field is a multidisciplinary domain that connects the rapidly evolving technology of information and communications technology (ICT) with the business and social environment (Willcocks et al., 2023).

1.2 Research philosophy

Scientists typically rely on different ontological and epistemological assumptions to develop their research methodologies (Easterby-Smith et al., 2021). Ontology pertains to the fundamental nature of reality and existence, whereas epistemology deals with the theory of knowledge and assists researchers in determining the most effective approaches to examine the world's underlying principles (Easterby-Smith et al., 2021).

From an ontological perspective, this dissertation is grounded in internal realism, which assumes the existence of a single reality but asserts that scientists can never directly access it. Facts, though concrete, remain indirectly accessible (Easterby-Smith et al., 2021). Conversely, epistemology examines the theories of knowledge, addressing how we come to know what we know (Easterby-Smith et al., 2021). This dissertation followed a positivist approach, emphasising the analysis of observable realities to generate universal principles. Positivism usually relies on strongly structured deductive reasoning, involves quantitative methods of analysis, and uses existing theories to develop hypotheses (Saunders et al., 2023).

This dissertation adopted a moderate version of positivism. Unlike strong positivism—which assumes a reality that exists independently of the observer and can be directly accessed through experiments that eliminate alternative explanations—a more moderate

form of positivism acknowledges that reality cannot be directly accessed (Easterby-Smith et al., 2021). To infer the nature of this reality, the researcher must follow an indirect approach by surveying samples of individuals, activities, or organisations (Easterby-Smith et al., 2021).

In a less strong version of positivism, several key theoretical components are essential for understanding and investigating phenomena. Willcocks et al. (2023) provide a compelling and comprehensive description of these components: a framework serves as a map of the phenomenon under study, outlining the main concepts, constructs, variables, and their relationships. A model, often a simplification, represents the relationships between the objects being studied. Concepts are abstract ideas or generalisations of multiple instances of an object, while constructs refer to the terms for concepts that are neither directly nor indirectly observable and are defined only in relation to the observable elements. Variables, on the other hand, are observable terms that change depending on constructs. Finally, hypotheses are operationalised propositions, taking the form of empirically testable conjectures or following procedural rules to infer other propositions (Willcocks et al., 2023).

1.3 Research questions and objectives

Based on this research's aim and its underlying philosophical assumptions, its guiding research question was formulated as follows:

1.3.1 General research question

Do businesses leverage open innovation and digitalisation to achieve their sustainability goals? If so, how do they do it?

1.3.2 Secondary research questions

1. How do businesses integrate open innovation to meet their sustainability goals?
2. What are the key motivations, enablers, obstacles, and success factors in adopting open innovation for sustainability?
3. What is the relationship between business digitalisation and environmental and economic sustainability?

1.4 Structure of the dissertation

This dissertation includes three interconnected publications. Publication I presents, from a conceptual perspective, how digital technologies promote open collaboration processes to drive environmental innovations. Publication II details a systematic literature review of the relationship between open innovation and sustainability-oriented innovation. Finally, Publication III illustrates a quantitative analysis of the relationship between business digitalisation and the environmental and economic sustainability of micro, small, and medium-sized enterprises (MSMEs) in Finland (Table 1).

Table 1: Thesis structure

Publication	Title	Research objective/research question	Research design	Research question associated
I	Open collaboration and digital technologies in the context of environmental innovations	Discuss, from a conceptual perspective, how digital technologies promote open collaboration processes to achieve environmental innovations.	Conceptual discussion	RQ 1 and RQ 3
II	Towards a comprehensive framework to analyse the benefits of openness for sustainability-oriented innovation: A systematic literature review	Systematically review the scientific literature on the role of open innovation in addressing the current and emerging societal and environmental challenges. To this end, the "what", "how", "who", and "why" of integrating external partners for sustainability	Systematic literature review	RQ 1 and RQ 2

		purposes were analysed.		
III	Business digitalisation as a driver of environmental and economic sustainability in micro, small, and medium-sized enterprises	Examine the relationship between business digitalisation, environmental sustainability, and economic sustainability, and study how this relationship differs between microenterprises and their larger counterparts?	Quantitative study	RQ 3

Source: own elaboration.

1.4.1 **Publication I: Open collaboration and digital technologies in the context of environmental innovations.**

Objective

This publication's primary objective is to discuss, from a conceptual perspective, how digital technologies promote open collaboration processes to achieve environmental innovations.

Main contributions

This publication aimed to offer insights into the strategic role of digital technologies and open collaboration in driving environmental innovations. To this end, it analysed how digital platforms, AI (artificial intelligence), and big data analytics facilitate the integration of external knowledge and collaboration among diverse partners to address environmental challenges. It also explored various open innovation mechanisms—such as crowdsourcing, customer co-development, and R&D alliances—that are instrumental in achieving sustainable development goals (SDGs) and fostering environmental-oriented innovations.

Further, it examined how digital technologies can be integrated with open collaboration processes to enhance the innovation capacity of firms and promote sustainable business practices. This publication outlined the central theme of business digitalisation, open innovation, and their impact on sustainability and identified gaps in the literature that are

addressed in the subsequent systematic literature review (Publication II) and the empirical paper (Publication III).

1.4.2 Publication II: Towards a comprehensive framework to analyse the benefits of openness for sustainability-oriented innovation: A systematic literature review

Objective

This publication primarily aimed to systematically review and synthesise the existing literature on open innovation in the context of sustainability-oriented innovation (SOI), identify the key mechanisms and frameworks used to assess the benefits of openness for sustainability-oriented innovation, and offer a comprehensive understanding of the factors that influence a successful SOI collaboration.

Main contributions

This publication developed a comprehensive conceptual framework that synthesises the main findings of the systematic literature review. This framework identified the key open innovation mechanisms, collaboration partners, and factors that influence the success of SOI processes.

The following research questions were addressed:

1. What are the sustainability goals pursued through open innovation approaches? This question aimed to identify the specific environmental and social objectives that firms intend to achieve through collaborative innovation efforts.

2. How are partners integrated into the innovation process? This question examined the open innovation mechanisms (e.g. crowdsourcing, co-creation, strategic alliances, among others) used to facilitate collaboration among partners.

3. Who are the key partners involved in the collaboration processes for SOI? This question explored the roles and contributions of different partners—such as businesses, non-profits, government agencies, and academic institutions—in driving SOI.

4. Why do companies and external actors engage in collaborative innovation for sustainability? This question explored the motivations and drivers behind the adoption of open innovation practices as well as the barriers and success factors that influence the effectiveness of different open innovation mechanisms.

1.4.3 Publication III: Business digitalisation as a driver of environmental and economic sustainability in micro, small, and medium-sized enterprises

Objective

This publication primarily aimed to examine the direct relationship between business digitalisation and improvements in economic sustainability, explore the potential mediating role of environmental sustainability, and assess the moderating role of company size in those relationships.

Main contributions

The guiding research question of this publication was this: What is the relationship between business digitalisation, environmental sustainability, and economic sustainability, and how does this relationship differ for microenterprises compared to their larger counterparts?

This publication examined the relationships between business digitalisation, environmental sustainability, and economic sustainability within MSMEs. Contrary to initial expectations, no direct and significant relationship was found between business digitalisation and the economic sustainability of MSMEs. This indicates that digitalisation alone does not directly enhance these enterprises' economic outcomes. Environmental sustainability plays a crucial mediating role in the relationship between business digitalisation and economic sustainability. While digitalisation does not directly impact economic sustainability, it significantly enhances environmental sustainability, which, in turn, positively influences economic performance.

The findings also indicate that company size moderates the relationship between business digitalisation, environmental sustainability, and economic sustainability. Specifically, the positive effects of digitalisation on environmental and economic sustainability are more pronounced in larger MSMEs than microenterprises. Microenterprises face unique obstacles, such as resource constraints and technical capabilities, which may limit their capacity to fully harness digitalisation for sustainability purposes.

2 Theoretical background

2.1 Business sustainability

2.1.1 Business sustainability: Emergence and recent developments

Businesses provide supply goods and services to society through commercial activities. However, these commercial activities, aimed at creating economic value and profits for companies, often cause severe environmental problems. Businesses must thus design strategies to create positive externalities for the environment (Busch et al., 2023).

Corporate sustainability emerged in the 1980s when civil society and government bodies raised alarms over unchecked economic growth that exceeded the capacity of natural resources (Bansal & Song, 2017). These groups, according to Bansal and Song (2017), pushed for sustainable development, and business schools, in addition to researchers who addressed this question, began analysing companies as interconnected systems within broader macroeconomic, political, social, and ecological frameworks (Bansal & Song, 2017).

Since then, the academic discourse on how firms respond to various social and environmental challenges, such as inequality, biodiversity loss, climate change, environmental pollution, natural resources degradation, and so on, particularly through corporate sustainability initiatives, has grown significantly, with much debate centred on how these initiatives can be economically feasible and aligned with business objectives (Linnenluecke & Griffiths, 2013).

Companies pursue corporate sustainability—which emphasises the strategic alignment of socially and environmentally responsible practices with business objectives (Bansal & Song, 2017)—for numerous reasons, including instrumental, ethical, stakeholder-related, and political motivations (Rasche et al., 2023). The context in which a company operates is crucial in shaping these motivations, with factors such as size, ownership structure, and target market all being significantly influential (Moon et al., 2023).

Researchers from various disciplines have explored the relationship between corporate sustainability initiatives and companies' financial performance using interdisciplinary approaches, thereby reflecting a growing interest in understanding the economic benefits associated with the adoption of sustainable strategies in the business sector (Busch et al., 2023).

Although the findings have been somewhat contradictory, a substantial body of literature supports a positive relationship (Busch et al., 2023). This is why environmental considerations should be essential in ensuring a company's economic performance. Ideally, economic targets can be met while simultaneously addressing social and environmental concerns. However, achieving synergy between environmental and

economic purposes simultaneously can sometimes create internal tensions within companies (Moon et al., 2023).

2.1.2 Environmental sustainability

Environmental sustainability encompasses the practice and process of renewing resources, reducing pollution, and eliminating environmentally harmful activities (Bakos et al., 2020). It encompasses a variety of corporate actions and strategies designed to minimise a company's environmental impact. Moreover, it involves the implementation of products, processes, and policies that minimise energy consumption and waste while promoting the responsible and efficient use of natural resources. This includes choosing materials and practices that are environmentally responsible and developing and implementing environmental management systems that enable the continuous monitoring and improvement of the ecological impact of human activities (Aguilera et al., 2021).

Environmental sustainability serves as a key indicator of competitive advantage (Tjahjadi et al., 2023). According to the resource-based view (RBV) of a firm argues, a business strategy focusing on resources that are valuable, rare, inimitable, and non-substitutable will enhance a firm's competitive advantage (Barney, 1991). This dissertation adopted the RBV argument that possessing distinctive resources provides a critical internal perspective for understanding competitive advantages (Reyes-Rodríguez & Ulhøi, 2022).

Promoting environmental sustainability includes demonstrating environmental responsibility and working towards reducing waste, resource depletion, pollution, and greenhouse gas emissions. Focusing on sustainability has been shown to positively impact firms' bottom lines through measures such as reducing energy and water consumption, encouraging suppliers to lower greenhouse gas emissions, reusing waste, and streamlining production processes (Amankwah-Amoah & Syllias, 2020).

For businesses, being environmentally sustainable implies achieving profitability through well-planned socially and environmentally conscious practices (Wiesner et al., 2018). Environmental sustainability initiatives, such as reducing pollution and energy use, enable firms to cut costs, enhance efficiency, and minimise future liabilities, ultimately improving the firm's financial position (Amankwah-Amoah & Syllias, 2020).

2.1.3 Sustainability-oriented innovation

Companies can achieve environmental sustainability through sustainability-oriented innovation, which encompasses developing novel solutions that cater to social, environmental, and economic dimensions and address each in a balanced manner. This approach does not seek to maximise any single dimension but aims to achieve satisfactory solutions that simultaneously consider all three of them (IPCC, 2022).

Innovations that focus only marginally on addressing environmental and social concerns are referred to as traditional innovations (Silvestre & Ţîrcă, 2019). Conversely, SOI is

characterised by an organisation's ability to promote sustainable development while generating economic, social, and environmental benefits (Rubio-Andrés & Abril, 2023). This type of innovation seeks to integrate sustainability principles into the core of business operations and strategies, ensuring that economic progress is not achieved at the expense of social welfare and the natural environment.

Sustainable innovation encompasses the discovery and creation of products, services, and markets that enhance sustainability (Busch et al., 2023). These innovations create value for stakeholders, society, and the environment while delivering private benefits to the company, such as higher profit margins, enhanced corporate reputation, greater attractiveness to potential employees, and improved employee well-being (Busch et al., 2023).

Sustainable innovation or SOI is an emerging field framed in the innovation management literature. Although the field of innovation is well-established and mature, both academically and among practitioners, many of the central discussions in the field—such as ideation, the innovation process, and its application and diffusion—have historically given limited attention to sustainability concerns (Meissner et al., 2024).

As suggested by Meissner et al. (2024), it is possible to claim that the negative environmental and social impacts began concurrently with the advent of modern innovation management, indicating a strong correlation between innovation management and unsustainable ecological and social effects (Meissner et al., 2024). The interplay between technology, innovation, and the environment has been widely discussed, as technological advancements are considered both a source of and a solution to a range of environmental challenges (Franceschini et al., 2016).

In a broader sense, SOI involves making deliberate adjustments to an organisation's philosophy, values, products, processes, or practices with the specific aim of generating and achieving social and environmental value in addition to economic gains (Adams et al., 2016). In line with Silvestre and Ţîrcă (2019), in this dissertation, the concept of innovation refers to initiatives that are novel to the firm or organisation implementing them.

The extent to which a particular innovation tackles environmental and social challenges differs (Silvestre & Ţîrcă, 2019). Traditional innovation prioritises profit, often overlooking side effects. There are three key types of sustainability-related innovation: green innovation, which reduces environmental impacts; social innovation, which focuses on societal welfare; and sustainable innovation, which balances environmental, social, and economic concerns but is complex and risky due to conflicting stakeholder demands (Silvestre & Ţîrcă, 2019). The need to consider a broad range of stakeholders limits individual enterprises from achieving competitiveness on their own. This demands a greater focus on collaborative efforts and ecosystem-based approaches to tackle complex issues within global settings (Meissner et al., 2024).

2.2 Open innovation

To maintain competitiveness, companies must continuously innovate with new products and services. However, when faced with knowledge and resource shortages, they turn to open innovation (OI) activities, seeking knowledge and collaboration from external partners (Dabić et al., 2023). The field of OI has provided valuable insights into how companies leverage knowledge inflows to boost internal innovation and knowledge outflows to expand external market opportunities for their innovations (Bogers et al., 2017).

Introduced by Chesbrough in (2003), OI has developed into a new paradigm for managing innovation. OI posits that companies should use ideas from both outside and within the organisation and follow both internal and external avenues to reach the market. OI processes integrate internal and external knowledge based on collaborative relationships with other actors, including suppliers, customers, universities, research institutes, competitors, startups, contractors, and public institutions (Bogers et al., 2018; Malodia et al., 2023).

A recent literature review suggests that research in this area has evolved through three distinct phases (Bertello et al., 2024). At first, pioneering scholars featured case studies of early adopters, such as large corporations and high-tech startups. The next phase widened the focus to encompass the role of users and customers in value co-creation and firms' capacities to absorb external knowledge, supported by quantitative methods. The third phase consolidated previous insights while addressing new challenges and opportunities, particularly in the context of digital transformation and policy pressures. This phase highlights the role of advanced technologies, such as IoT (Internet of Things), big data, and AI, in facilitating collaboration and innovation (Bertello et al., 2024).

Recently, OI research subjects have expanded beyond traditional patterns and positive effects to include diverse areas, such as the OI paradox as well as its application in various industries like financial services, food, and service sectors (Dahlander et al., 2021). The other areas of focus include holistic or citizen OI and managing OI (Dahlander et al., 2021). Additionally, the literature has been largely unbalanced, primarily highlighting OI's benefits while overlooking its associated costs (Dahlander et al., 2021).

The transition towards a more sustainable and digital society is being shaped by open innovation practices, as addressing today's systemic, interrelated, and complex societal challenges demands collective action (Bertello et al., 2024). For instance, emerging technologies can help build more resilient innovation ecosystems, though they also require organisations to develop specific resources, skills, and competencies (Bertello et al., 2024). Additionally, as suggested by Bertello et al. (2024), there is ample opportunity to offer new solutions to grand challenges while learning how to advance the concept of OI.

2.3 Business digitalisation

Technologies like the internet, AI, and cloud computing are driving the digital economy's expansion, with a profound impact on industrial development and economic growth (Guo et al., 2023). Digitalisation involves incorporating digital components into product or service offerings (Kumar et al., 2024). Digitalisation is a key pillar of Industry 4.0, representing a new production paradigm focused on digital transformation. This approach is characterised by the integration of advanced digital technologies with physical production processes, as well as with products and services, creating a synergy that enhances efficiency, flexibility, and innovation (Holl & Dellepiane, 2022).

Digital technologies are generally defined as the convergence of connectivity, vast and dispersed information, and communication and computing technologies (Schöggl et al., 2023). They encompass a variety of tools, including AI, cloud computing, IoT, robotics, smart sensor devices, big data analytics (BDA), high-speed infrastructure (HSI), and blockchain (Ardito, 2023). These digital technologies are now widespread, allowing companies to optimise their existing processes, improve their business value proposition, and enhance their customer experience (Etienne Fabian et al., 2024).

Digitalisation has become a vital resource, with digitally advanced firms considering digital technologies and capabilities as their most important strategic asset. Firms can achieve high levels of digitalisation by using digital technology to substantially alter the multiple value-generating components of their business model, such as business operations, relationship management, and strategic partnerships (Etienne Fabian et al., 2024). Firms that strategically invest in digital technologies can also achieve better performance; however, as their digital investments grow, they often face a digitalisation paradox, where their expected performance gains are not realised.

Digitalisation's relevance lies in its role as an emerging trend that drives businesses of all sizes to boost their digital capabilities across all dimensions to remain competitive (Alsufyani & Gill, 2022). Since digital technology reshapes an organisation's internal and external components and their interactions, it can influence its performance outcomes both directly and indirectly. However, there remains uncertainty about what to measure and how to assess the impact of digitalisation on performance outcomes (Alsufyani & Gill, 2022).

Digitalisation can also accelerate the economic transition towards a more resource-efficient and resilient circular economy-based production system (Kumar et al., 2024). While digitalisation can improve environmental sustainability performance, companies must elevate their overall level of digitalisation to fully realise these benefits (Kumar et al., 2024). As is evident from the above discussion, the relationship between digital transformation and sustainable performance has not been fully elucidated (Kumar et al., 2024).

3 Methodology

3.1 Research design for publication I: Conceptualising

Publication I is a conceptual exercise aimed to explore and approach the foundational concepts of this dissertation. Conceptual papers often integrate various concepts, literature streams, and theories (Jaakkola, 2020). While both empirical and conceptual papers aim to generate new knowledge by drawing on carefully chosen sources and adhering to established norms, conceptual papers derive their arguments from the integration of existing concepts and theories rather than conventional data (Jaakkola, 2020).

Conceptual papers are recognised as a distinct type of research because they represent the first step in theory building and provide a foundation for conducting empirical studies (Rocco et al., 2022). A concept is an abstract idea, a mental depiction of something in reality, or a sense that something exists in a specific way. Publication I is a theory synthesis paper that aimed to integrate various concepts or literature streams.

Theory synthesis papers offer fresh or enhanced perspectives on a concept or phenomenon by connecting previously unlinked elements (Jaakkola, 2020). Integration papers link previously distinct phenomena, discovering a novel, simplified, and higher-order perspective on their relationships. This process entails combining diverse elements into a unified whole.

Integration leads to overarching concepts that reconcile previous findings, address contradictions or puzzles, and introduce new viewpoints (MacInnis, 2011). The idea of conceptual pieces serving as a bridge or link is significant in the management field, where numerous interesting theories exist. While these theories advance our thinking, they are often difficult to test, resulting in sophisticated theories that remain empirically untested (Gilson & Goldberg, 2015).

In conceptual papers, concepts are developed by defining a problem, linking concepts, or questioning the existing relationships (or their absence) between concepts (Rocco et al., 2022). Conceptual papers typically do not involve data, as they are primarily concerned with developing and suggesting new links among constructs (Gilson & Goldberg, 2015). Consequently, the evaluation of conceptual papers is based on the quality of the arguments presented.

3.2 Research design for publication II: Systematic literature review

A systematic literature review aims to extract and synthesise the key findings from a broad array of studies on a specific research topic (Clark et al., 2021) by integrating, synthesising, and consolidating the current state of knowledge in any field (Fan et al., 2022).

Scholars write literature reviews for different aims and situations. Generally, there are three primary contexts for writing a systematic literature review (SLR) (Kraus et al., 2020): a standalone review article on a specific topic; an introduction to an empirical paper providing the basis for hypotheses; or as the initial stage of a larger research project.

This dissertation conducted an SLR, as it can be considered more useful than a traditional literature review. SLRs offer a more rigorous and structured approach to synthesising existing research (Kraus et al., 2020). In business and management, an SLR has its foundations in the sciences and clinical disciplines. The primary focus of an SLR is to ensure that the review process is thorough, transparent, and can be replicated. Moreover, by using explicit and systematic methods, selection bias can be minimised and reliable findings can be attained (Fan et al., 2022).

SLRs assist researchers in organising, analysing, and summarising academic literature while maintaining the transparency of their process (Kraus et al., 2024). They must be assessed and evaluated as rigorously as empirical articles (Snyder, 2019). In Publication II, the following steps were undertaken to conduct SLR:

3.2.1 Establishing guiding research questions

The research was guided by four key questions:

- What are the sustainability goals pursued through open innovation approaches? (the what)
- How are partners integrated, and what open innovation mechanisms are being used? (the how)
- Which secondary stakeholders are involved in the collaborations for SOIs? (the who)
- Why do companies and external actors set up collaborations to innovate with a sustainability purpose? (the why)

3.2.2 Searching for the relevant studies

- Keywords related to sustainability-oriented innovation and open innovation were used to search for relevant studies in the Web of Science database.
- The search included terms like "sustainability-oriented innovation", "eco-innovation", "open innovation", and "collaboration", among others.
- The search covered publications between 2000 and 2021 and included titles, abstracts, and keywords to improve the probability of finding relevant studies.

3.2.3 Eligibility assessment

- Initially, 569 publications were identified. After applying filters for the timeframe, document type, and language, 512 articles were selected for further screening.
- The titles, abstracts, and keywords each article were reviewed to determine its relevance.
- For the articles that demanded further analysis, their full text was examined, resulting in a final selection of 35 articles that specifically addressed the relationship between open innovation and SOI.

3.2.4 Data extraction and synthesis

- Descriptive analysis and content analysis were performed on the selected articles.
- A codebook was designed to describe each article, including aspects such as the level of analysis, source of information, and theoretical perspective.
- The categories related to the research questions (sustainability goals, partners involved, open innovation mechanisms, and reasons for collaboration) were identified and analysed using ATLAS.ti software.

3.2.5 Results of the SLR: Descriptive and content analysis

- Descriptive analysis: An overview of the research studies was provided. The analysis revealed the multilevel nature of SOI, with studies conducted at organisational, project, and inter-organisational levels. Most of the studies employed qualitative methodologies, and the primary theoretical perspectives included stakeholder theory, industrial ecology, network theory, and the absorptive capacity framework.
- Content analysis: Content analysis allows scholars to examine a small to medium corpus of articles using both quantitative and qualitative techniques. This dissertation used a quantitative approach to perform content analysis objectively by quantifying the specific units of analysis (Kraus et al., 2022). Content analysis identified the main sustainability goals (environmental, social, and economic) and the specific open innovation mechanisms used (crowdsourcing, lead-user workshops, alliances, joint ventures, and so on). It also highlighted the variety of

partners involved (suppliers, customers, higher education institutions, private non-profits, and so on) and the motivations, drivers, barriers, and success factors that influence collaborative SOI processes.

3.3 Research design for publication III: Explanatory quantitative study

Publication III applied a causal logic to explain the relationship between business digitalisation, environmental sustainability, and economic sustainability based on survey data. The prevailing epistemology behind survey research methods is positivism (Easterby-Smith et al., 2021). Survey designs are guided by an internal realist ontology, and their validity concerns are quite similar to those found in strong positivist studies (Easterby-Smith et al., 2021), although they represent a weaker form of positivism compared to experiments.

Positivism is based on the assumption that there are regular, verifiable patterns in human and organisational behaviour, even though these patterns can be difficult to discern and explain because of the numerous factors and variables at play (Easterby-Smith et al., 2021). Consequently, survey research typically employs cross-sectional designs, which enable the simultaneous measurement of multiple variables and the examination of potential associations (Easterby-Smith et al., 2021). Inferential surveys are designed to identify the relationships between variables and concepts regardless of any prior assumptions or hypotheses about the nature of those relationships.

3.3.1 Data collection technique

The data were collected via a web-based survey, encompassing both firm- and study-theme-related constructs. The respondents were identified from the database of a local supporting business organisation. This database was selected because it is the most comprehensive list available (to the best of the researcher's knowledge) of a large number of small, active companies that were difficult to find (most databases cover larger companies).

3.3.2 Sampling frame

The empirical context of this study was based on a sample of 95 MSMEs in the Päijät-Häme region of Southern Finland, which has a population of approximately 206,000 (The Regional Council of Päijät-Häme, 2024).

The initial sample included approximately 3,000 firms with a maximum of 250 employees, which is in line with the threshold set by the Federation of Finnish Enterprises for the Päijät-Häme region. This sampling process resulted in 98 valid responses. However, after data screening, three questionnaires were excluded from the analysis to

avoid bias, as the respondents indicated that they were leading companies with more than 249 employees.

3.3.3 **Respondent demographics**

The unit of analysis was the company, while the unit of observation was the manager or owner of the company. Managers and owners were selected as respondents due to their expected adequate knowledge of their companies' operations, digitalisation orientation, and the environmental and economic sustainability achieved by the companies they lead (Saunila et al., 2019).

Table 2 presents the main characteristics of the companies. The majority were microenterprises (62%), with an average of three employees, and 42.4% had only one employee besides the manager/owner. Additionally, 39% of the companies were well-established, having been in operation for more than 20 years, while the second-largest group consisted of companies founded within the last five years (32%).

Table 2: Sample description

Characteristics	Frequency (n)	Percentage (%)
Industry type		
Production	26	27%
Services	69	73%
Age (years)		
5 or fewer	30	32%
6–10	12	13%
11–15	11	12%
16–20	5	5%
More than 20	37	39%
Customer base		
B2C	26	27%
B2B	69	73%
Number of employees		
0–9 (Micro)	59	62%
10–49 (Small)	23	24%
50–249 (Medium)	13	14%
Total	95	100%

Source: Author's own elaboration.

3.3.4 **Variable measurement**

Dependent variable

Economic sustainability, measured using two items (Table 3) scored on a 4-point Likert scale ranging from 1 (weak) to 4 (excellent), was considered to be a firm outcome, reflecting the improvements in its profitability and overall economic sustainability.

Independent variable

Business digitalisation was measured with five items (Table 3) and scored on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items were adapted from Lee and Roh (2023) and Proksch et al. (2021).

Mediating variable

A single item was used to measure the companies' overall environmental sustainability (Table 3). The participants were asked to evaluate their companies' environmental sustainability (minimising environmental impact) on a scale ranging from 1 (weak) to 4 (excellent).

Table 3: Constructs and items

Construct	ID	Items	Mean	SD	Min	Max
Business digitalisation	DIG1	Our company's equipment and functions create good conditions for utilising digitality.	3.61	1.28	1	5
	DIG2	The processes of our company utilise a lot of digitality.	2.43	1.24	1	5
	DIG3	We utilise digitalisation in a key part of our products.	3.26	1.38	1	5
	DIG4	We use digitalisation as a	3.47	1.23	1	5

		key part of our services.				
	DIG5	Our service portfolio includes a lot of digital services.	2.52	1.39	1	5
Economic sustainability (in relation to other similar companies in the industry)	ECON1	The profitability of our company is…	2.80	0.66	1	4
	ECON2	The economic sustainability of our company (operating in an economic balance that is not based on debts) is…	2.94	0.80	1	4
Environmental sustainability (in relation to other similar companies in the industry)	ENV	The environmental sustainability of our company (minimising environmental impact) is…	3.15	0.618	1	4

Source: Author's own elaboration.

Moderating variable

A dummy variable was created based on the number of full-time employees to account for the effect of firm size on the hypothesised relationships. The definitions and classifications for MSMEs vary by country, but this study followed the classification proposed by the OECD and European Commission, which defines microenterprises as having fewer than 10 employees, small enterprises as having between 10 and 49 employees, and medium-sized enterprises as having between 50 and 249 employees (Di Bella et al., 2023; OECD, 2023). Accordingly, the dummy variable was assigned a value

of 1 for microenterprises (fewer than 10 employees) and 0 for small or medium-sized enterprises.

Control variables

Control variables were included to address potential biases, such as firm age, customer base (B2B/B2C), and sector (production vs. services). Firm age and customer base were considered due to their impact on digitalisation and sustainability practices, while sector was included for its influence on profitability and the interaction between products and processes.

3.3.5 **Bias**

The potential for non-response bias was evaluated by comparing the responses of 20 early participants with those of 20 late participants across all the study items. An analysis of variance at the 5% significance level revealed no statistically significant differences between the two groups.

Given that the responses for this study's constructs were collected through a cross-sectional survey, the possible impact of common method bias (CMB) was thoroughly evaluated. CMB typically arises when dependent and independent variables are measured within the same survey using the same source and response method (Kock et al., 2021). To mitigate CMB, procedural and statistical techniques were applied in line with recommendations from Podsakoff et al. (2003).

Procedural controls included offering participants clear instructions, ensuring survey anonymity and confidentiality, and employing straightforward language to avoid ambiguity. The length of the questionnaire was kept short to reduce respondent fatigue and cognitive effort, which can help reduce CMB (Kock et al., 2021).

For statistical controls, Harman's single-factor test was conducted using SPSS 26.0, which revealed five primary factors that explained 86.47% of the total variance, with the largest factor accounting for 38.94%, indicating no dominance. A full collinearity test performed using SmartPLS 4.0.9.3 revealed that all the variance inflation factors (VIF) remained below the threshold of 5, as recommended by Hair et al. (2019). CMB was thus concluded to be not a major concern.

3.3.6 **Data analysis technique**

Research models that involve multiple constructs, variables, and interrelationships are typically analysed using structural equation modelling (SEM). SEM offers flexibility in testing complex models by allowing researchers to include multiple predictors and outcome variables, develop latent (unobservable) variables, and evaluate the mediation and moderation relationships within a single model (Nitzl, 2016).

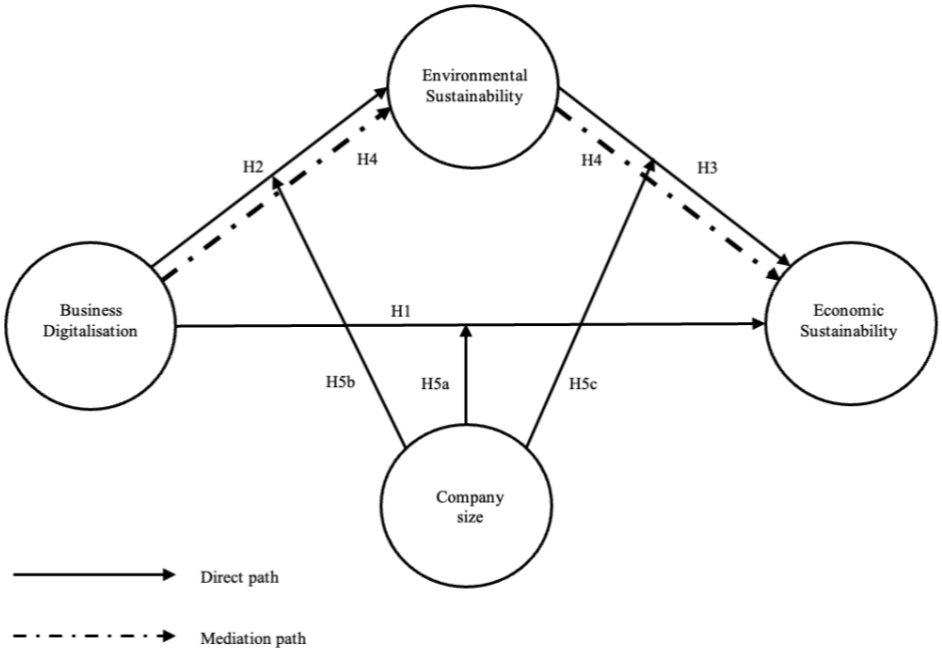
There are two kinds of estimators for SEM: covariance-based and variance-based estimators (Benitez et al., 2020). Partial least squares structural equation modelling (PLS-SEM), a type of structural equation modelling like its sibling CB-SEM, was developed for research models with weak theoretical foundations where various potential influences need testing (Nitzl, 2016). With a weak theoretical basis, it is unlikely that CB-SEM's psychometric assumptions are met for the observed indicators, leading to unacceptable results for data sets not derived from long-term measurement processes (Nitzl, 2016).

Following the guidelines of Hair Jr et al. (2022), PLS-SEM, a variance-based SEM approach, was selected due to its suitability for exploratory research, its efficiency with small sample sizes and different measurement scales, and its robustness in handling non-normal data. The minimum sample size was ensured by following Nitzl (2016) to maintain statistical relevance. PLS-SEM also supports the use of single- and multi-item measures within the same model and is ideal for examining complex models with mediating and moderating effects. Additionally, it offers higher statistical power than CB-SEM (Hair Jr et al., 2022).

PLS-SEM has been the main method for estimating structural equation models in information systems, management, and business research, research fields that often involve complex problems that demand the development and measurement of theoretical concepts (Benitez et al., 2020) as well as the investigation of their relationships. These theoretical concepts are usually depicted as constructs within a structural model (Benitez et al., 2020).

This research's proposed theoretical model was outlined in structural relationships based on equations linking conceptual variables (Figure 1), formalising and visually representing the theoretical model (Sarstedt et al., 2016). The conceptual variables refer to the general ideas or abstract concepts measured in the research. The constructs serve as the statistical representations of these variables within the structural equation model (Sarstedt et al., 2016). The proposed model was transformed into a statistical model, which involved translating the theoretical concepts and their hypothesised relationships into a structural framework (Benitez et al., 2020).

Figure 1: Proposed theoretical model.



Source: Author's own elaboration.

3.3.7 **Validity and reliability**

PLS path models comprise two linear equation sets: the measurement model (outer model) and the structural model (inner model). The former defines the relationships between a construct and its observed indicators, while the latter maps the relationships between the constructs (Henseler et al., 2016).

The assessment of measurement models involved evaluating several key criteria to ensure the reliability and validity of the constructs being measured. Indicator reliability was assessed to determine the consistency of the individual items or indicators that constitute a construct, ensuring that each indicator reliably reflected the construct. Internal consistency measures, such as Cronbach's alpha and composite reliability, were used to evaluate how well the items within a construct correlated with one another.

Convergent validity, primarily assessed by calculating the average variance extracted (AVE), was measured to determine the proportion of variance captured by the indicators of a construct, thereby ensuring that the indicators adequately reflected the underlying theoretical construct. Further, discriminant validity was evaluated using the heterotrait-monotrait ratio (HTMT) to analyse the extent to which a construct was distinctly different from the other constructs in the model and ensure that it did not excessively overlap with others (Hair Jr et al., 2022).

Several critical steps were undertaken to ensure the reliability and validity of the structural model. One step involved performing a two-tailed bootstrap procedure with 10,000 subsamples, which enabled the determination of the statistical significance of the path coefficients. Furthermore, the VIF was calculated to identify any potential multicollinearity issues. According to Hair Jr et al. (2022), it is recommended that the VIF values remain below 5 to avoid substantial multicollinearity problems that could compromise the reliability of the results.

Finally, the coefficient of determination (R^2) was assessed to measure the model's explanatory power. This coefficient reflects how effectively the independent variables explain the variance in the dependent variable, which is essential for understanding the model's overall robustness and relevance.

4 Results and discussion

This section highlights the main results of the dissertation. Regarding Q1—How do businesses integrate open innovation to meet their sustainability goals?—the findings reveal that mechanisms such as crowdsourcing, customer co-development, and R&D alliances are instrumental in achieving SDGs and fostering environmental-oriented innovations. Moreover, digital technologies promote open collaboration processes that aim to achieve environmental innovations; they enable active collaboration and interaction among various stakeholders, including companies, communities of experts, and consumers. Such a collaborative approach is crucial for addressing environmental challenges and achieving sustainability goals.

Regarding Q2—What are the key motivations, enablers, obstacles, and success factors in adopting open innovation for sustainability?—a clear dominance of open innovation mechanisms aimed at developing environmental innovations than those focused on the triple bottom line (economic, social, and environmental benefits) was identified. The different open innovation mechanisms identified include the following: a) inbound mode: crowdsourcing, lead-user workshops, intermediation, and experiments and discussion sessions; b) coupled mode: ten mechanisms were identified, including alliances, business-non-profit engagement, co-creation, joint ventures, cooperation, collaborative innovation contests, coopetition, cross-sector partnerships, joint development projects, and innovation networks; c) partners: collaboration processes usually involved a range of partners, including suppliers, customers, other businesses, government, higher education institutions, private non-profit organisations, and communities.

Most of the collaborations for environmental innovations were found to be established with other companies, customers, and suppliers. The motivations to collaborate for SOI (sustainability trends, human capital, financial gains, and organisational benefits) were identified along with their internal drivers (sustainability strategies, internal culture, capabilities, and top management commitment), external drivers (stakeholder pressure, demands for sustainable products, government subventions, and digitalisation), barriers (finding suitable partners, cultural differences, contract difficulties, and lack of absorptive capacity), and success factors (effective communication, trust-based relationships, long-term alliances, and sharing common knowledge). Chiefly, the SLR produced an integrative conceptual framework that synthesised the identified mechanisms, partners, motivations, drivers, barriers, and success factors in open innovation for sustainability.

Regarding Q3—What is the relationship between business digitalisation and environmental and economic sustainability?—no direct and significant relationship was found between business digitalisation and the economic sustainability of MSMEs. Contrary to initial expectations, simply integrating digital technologies within business operations did not directly translate to improved economic outcomes.

However, the critical mediating role of environmental sustainability in this relationship was highlighted. Digitalisation was found to contribute to economic sustainability indirectly by enhancing environmental practices, implying that digitalisation's economic benefits can be realised only when these digital efforts lead to improvements in environmental sustainability.

Moreover, business digitalisation was found to positively affect environmental sustainability. Integrating digital technologies helps companies adopt better environmental practices, which, in turn, leads to greater overall sustainability. A positive relationship between environmental sustainability and economic benefits was also found: companies that improve their environmental practices enjoy significant economic gains, thus suggesting that efforts to minimise environmental impact can generate better financial performance.

Lastly, in the relationship between environmental and economic sustainability, firm size was identified as a moderating factor. While high levels of environmental sustainability generally led to improved economic outcomes, this relationship was less pronounced for microenterprises than small and medium-sized enterprises. Smaller firms evidently face more challenges in converting their environmental efforts into economic gains, thus highlighting the need for tailored support mechanisms to help them achieve their sustainability goals.

5 Conclusions

5.1 Theoretical contributions

This dissertation makes several theoretical contributions to the fields of corporate sustainability, innovation management, and information systems by integrating digitalisation and open innovation as drivers of sustainability in the business context. The three publications collectively advance the theoretical understanding of how digitalisation and open innovation can foster business sustainability.

The first key contribution is that this dissertation extends the current understanding of how digital technologies facilitate open collaboration processes that aim to achieve environmental innovations. This research highlights the key role of digital technologies in transforming societies, cultures, and economies, encouraging environmental attitudes and behaviours, collective climate actions, and changing business practices. This digital imperative also demands companies to review their inter-firm collaboration and coordination models to satisfy the expectations of strategic or potential customers. Establishing governance structures and mechanisms is thus essential to reconcile the points of divergence between partners in environmental innovation. The main contribution of this finding is that it connects three fields—corporate sustainability, innovation management, and information systems—that have rarely been addressed together in the literature but that are extremely important in practice for the environmental innovation performance of companies.

This research also contributes to the literature by demonstrating the "what", "how", "who", and "why" of open innovation processes that guide businesses in their innovation efforts towards sustainability. By systematically examining the mechanisms, motivations, drivers, barriers, and success factors of open innovation in SOI, this research offers an integrative conceptual framework, one that advances the understanding of how businesses can integrate external partners and innovate sustainably. This conceptual contribution offers a structured approach for future research and practical guidance for policymakers and managers in fostering sustainable innovation.

Finally, this dissertation examined the relationships between business digitalisation, environmental sustainability, and economic sustainability, focusing on the mediating role of environmental sustainability and the moderating role of company size. This research challenges the prevailing assumption that business digitalisation directly improves economic sustainability—it reveals a lack of significant association between digitalisation and economic performance, suggesting that increased digitalisation does not necessarily lead to immediate or direct economic benefits for companies. Moreover, while digitalisation may not directly enhance economic performance, it significantly improves environmental sustainability. This, in turn, positively influences economic outcomes, indicating environmental sustainability's mediating role in the relationship between digitalisation and economic performance.

Additionally, the research underscores the strategic importance of aligning digitalisation efforts with environmental sustainability to achieve long-term competitive advantages. Moreover, it sheds light on the unique challenges and opportunities faced by MSMEs in pursuing sustainability. These findings advocate a strategic approach, one grounded in the RBV, suggesting that companies leveraging digitalisation to enhance environmental sustainability can indirectly increase their economic performance. This strategic orientation demonstrates that digital capabilities can create a sustained competitive advantage by optimising business processes and addressing environmental concerns.

Furthermore, the study offers insights into the challenges and opportunities that MSMEs encounter in their pursuit of sustainability. It highlights the resource and capacity constraints of small businesses and suggests that these firms can leverage intangible resources, such as social capital, to support their sustainability initiatives. The study also discussed the constraints smaller firms face in environmental management and sustainable development. This research contributes to the intersection of information technology and management literature by demonstrating how digital capabilities can optimise business processes and create value. It emphasises the role of strategic alignment with environmental and sustainability issues in translating digital investments into competitive advantages.

5.2 Managerial and practical contributions

The research findings can be used to improve the managerial role in relation to sustainable business. Digital technologies are critical drivers of collaborations for sustainability purposes: they offer new types of products and services with societal benefits. By leveraging digitalisation, managers can engage in open innovation to access diverse knowledge and ideas for sustainability, which can lead to the development of environmentally friendly products and services. Furthermore, this research has identified and synthesised the main mechanisms used to establish collaborative processes that contribute to sustainability. It also offers an overview of the main factors for the success of collaborative processes, thereby helping to reduce the likelihood of failure in collaborations between companies and their external partners.

The findings hold important implications for small business managers and policymakers as well. The shift towards environmentally sustainable practices has been found to be more complex for small companies than for larger ones due to their limited financial resources and strong dependence on economic performance indicators to grow and survive. Although economic benefits should not be the only motivation for improving their environmental practices, MSMEs must thus recognise the economic benefits of embracing environmental sustainability. If companies do not realise the business potential of environmental sustainability, their owners will lack incentives to prioritise environmental practices in their core business strategies.

Additionally, previous research suggests that, for smaller companies to benefit economically from environmentally sustainable management, owners and entrepreneurs must strategically rethink their approach to sustainability. This involves considering not only a win-win relationship in economic terms but also the benefits they can achieve in terms of business reputation and meeting customer expectations. Finally, companies must balance short-term financial goals with long-term sustainability objectives. This entails making strategic investments in technologies and practices that may not yield immediate returns but are crucial for the companies' future growth and environmental sustainability.

5.3 Future research and limitations

To advance both theoretical knowledge and practical applications in the field of sustainable business practices, this dissertation proposes several areas for further investigation.

First, this research highlights the importance of adopting a temporal and relational perspective in studying open innovation for SOI, an approach that helps determine which partners are most critical at different stages of the innovation process and how their integration impacts the sustainability performance of firms. This perspective encourages further investigation into the timing and relational dynamics of collaborative innovation efforts.

This research also suggests the need to analyse how motivations, drivers, barriers, and success factors vary according to contingency factors and firm characteristics. Doing so would provide a more complete understanding of the factors that influence successful sustainability-oriented collaborations.

Moreover, the paradoxical view on collaboration for SOI can be valuable, as it highlights the tension between sharing technical knowledge and protecting proprietary information. Exploring the role of this tension and paradox in SOI could be a promising research direction, as it would allow researchers to analyse competitive relationships and find ways to address the emerging conflicts.

Lastly, given the owner-manager-entrepreneur centrism in microenterprises, future research should examine how individual owner characteristics interact with company-level factors when analysing companies' environmental sustainability. This approach would strengthen the understanding of the relationship between digitalisation and the environmental and economic sustainability of small companies and offer insights into how personal attributes and organisational dynamics influence sustainability outcomes.

To provide a comprehensive understanding of this study's scope and its potential constraints, its limitations should be acknowledged. One potential limitation is social desirability bias. As proposed by Heras-Saizarbitoria et al. (2020), environmental sustainability measures primarily based on managers' perceptions or opinions may be

influenced by social desirability or self-reporting bias. However, in line with Wang et al. (2023), we implemented several strategies to mitigate the influence of social desirability bias and encouraged participants to supply honest perspectives. Additionally, considering that this research provides only a snapshot in time, longitudinal studies are needed to address the endogeneity concerns in the proposed research model. Endogeneity can compromise the key conditions for claiming causality (Zhang et al., 2022), and the suggested relationships should be interpreted more as robust correlations rather than causal slinks.

Recent innovation management research has highlighted that, even for innovative efforts focused on sustainability, economic rationality prioritises profitability over achieving a balance with socioecological goals. Consequently, the benefits of a firm's sustainable practices are evaluated based on their contribution to its overall economic objectives (Meissner et al., 2024).

Financial incentives to address sustainability targets can suggest an instrumental perspective on companies' engagement in sustainable business practices (Busch et al., 2023). Rather than viewing this as a limitation, it can be seen as an initial step or level of sustainability engagement—necessary but not sufficient for companies to generate a positive impact on the environment and society.

This dissertation was conducted at the firm level, considering the historical responsibility private companies have had in terms of sustainability and responsibility. However, sustainability is also an individual, organisational, inter-organisational, ecosystem, and societal issue that should be examined at different levels of analysis. Future research should explore these dynamics at multiple levels to gain a more holistic understanding of sustainability practices and their impacts.

Though sustainability is ultimately achieved at the system level, with companies being just one component of that system (Barnett et al., 2022), and companies alone cannot ensure the sustainability of the entire system, they do hold the responsibility of managing their interdependence and influence within the system in a way that contributes to the overall sustainability (Barnett et al., 2022). This dissertation aims to be relevant by demonstrating how business sustainability can be advanced through open innovation processes and the integration of digitalisation into business functions.

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Publication I

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Open Collaboration and Digital Technologies in the Context of Environmental Innovations

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Abstract

Digital technologies are a valuable strategy for finding, identifying, combining and integrating external knowledge, as well as for generating new organizational forms to develop innovative solutions. At the same time, digital technologies are allowing a more active collaboration and interaction among companies, communities of experts, and consumers in order to address environmental-oriented innovation challenges. Environmental innovation refers to the development of new or improved products and the creation of new processes and business models that bring benefits to the natural environment. In that sense, the main objective of this study is to discuss, from a conceptual perspective, how digital technologies promote open collaboration processes to achieve environmental innovations. We analyze crowdsourcing, customer co-development, and R&D alliances as mechanisms to achieve Sustainable Development Goals in general, and environmental-oriented innovations in particular. Our study expands the argument that collaboration with outsiders is a key capability to advance towards environmental innovation and to acquire and provide unique resources and knowledge to facilitate the environmental innovation process.

Keywords: environmental innovation; circular economy; open collaboration; stakeholders; sustainability; digital technologies.

Introduction

In order to contribute to sustainable development, companies are required to formulate corporate strategies that deal with the most important today's environmental challenges. According to United Nations, there are many people who still lack access to wastewater management and sanitation facilities. On another hand, the continuous increase in sea levels, extreme weather conditions, greenhouse gases, overfishing, ocean acidification and eutrophication, and the transition towards more sustainable energy systems are also serious environmental challenges requiring an exceptional attention of society (United Nations, 2018). However, the most critical problem of our days is climate change, considering that itself is responsible for the most above-mentioned factors. Climate change is far from being exclusively an environmental problem and also affects the social development and the economic dimension (Silvestre & Ţîrcă, 2019).

Thus, how companies can start to think about the environmental effects of their business activities in order to improve their sustainability performance? Due to societal pressures, firms "are searching for ways to do things differently while also seeking opportunities for growth" (Geradts & Bocken, 2019, p.79) which suggests that environmental challenges should be addressed from an innovation-centered approach (Klewitz & Hansen, 2014) with a view to helping businesses transition to environmental sustainability (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016). This approach is commonly known as environmental innovation, and it refers to the development of new or improved products and the creation of new processes and business models that bring benefits to the natural environment (Geradts & Bocken, 2019). Environmental innovations, compared with traditional innovations, have a higher degree of complexity, uncertainty and unpredictable financial returns, and require disrupting decisions (Kennedy, Whiteman, & van den Ende, 2017; Kralisch et al., 2018).

Due to the added complex and uncertain character of environmental innovations, many scholars have claimed that collaboration with external players are key mechanisms to identify business opportunities associated with environmental challenges (Kennedy et al., 2017). Indeed, a decade and a half ago, literature has highlighted the importance of going beyond

the conventional boundaries of the firm to foster development of new products through open innovation (Chesbrough, 2003). According to the open innovation paradigm, firms cannot innovate alone. Hence, firms need to collaborate to get the right knowledge that allow them developing new sustainable products, processes or businesses models (Kennedy et al., 2017).

In an attempt to analyze the role of key stakeholders in the eco-innovation process, Carrillo-Hermosilla, Del Río, & Könnölä (2010) assert that a successful environmental innovation requires participation and cooperation among different partners such as academia, public sector, business, consultants, and other stakeholders, in order to find new ideas inside and outside the company. He, Miao, Wong, & Lee (2018) expand this argument claiming that cooperation with outsiders is needed to acquire and provide unique resources, capabilities, and knowledge for facilitating the environmental innovation process.

Through open collaboration firms can obtain valuable knowledge to identify environmental solutions, as well as enhancing the legitimacy and social license to operate. In this context, digital technologies are an important strategy for finding, identifying, combining and integrating external knowledge, as well as generating new organizational forms for the development of innovative solutions. For instance, through digital platforms, a diverse group of entities (e.g. experts, companies, users, universities, R&D centers, etc.) interact in virtual environments in order to transfer and integrate knowledge for solving environmental challenges (IBM Institute for Business Value, 2020).

Thus, digital platforms are mechanisms through which potential "solvers" can generate solutions to important innovative challenges (Abbate, Codini, & Aquilani, 2019). At the same time, digital technologies are allowing more active collaboration and interaction among companies, communities of experts, consumers (Hara, Komatsu, & Shiota, 2018; Rayna & Striukova, 2020) and other external actors through tournaments, open calls and crowdsourcing (Boons & Stam, 2019) or through intermediary platforms (e.g. *InnoCentive*, *IdeaConnection*, or *Innoget*), in order to address environmental innovation challenges (OECD, 2018). In that sense, the main objective of this article is to discuss, from a conceptual

perspective, how digital technologies promote open collaboration processes to achieve environmental innovations.

Environmental Innovations

The transition to a greener economy demands several incremental and radical changes, involving both mature and new emerging sectors (Rosa, Sassanelli, & Terzi, 2019). The best example of environmental innovation are circular economy innovations, which can be understood as an economic model that seeks to reduce the harmful effects of resources consumption, looking for ways to design new materials or systems (Rosa et al., 2019). The circular economy has a clear relation with the United Nations Development Goal 12 of "Responsible Production and Consumption". However, the circular economy have cross-cutting applications to most of the objectives proposed by the United Nations (Demirel & Danisman, 2019).

Circular eco-innovation is a term used to refer to environmental innovations that target resource recirculation in reuse, recycling and renovation loops, and are key to addressing today's major environmental challenges (Demirel & Danisman, 2019). These principles of circular economy innovations are applied at the micro (firm and consumer), meso (eco-industrial parks), and macro (cities, regions, and nations) levels (Demirel & Danisman, 2019). At the same time, innovation trends in the circular economy can be classified in technology push, including strategies such as the production of reusable and longer-life materials, and market pull, such as green consumerism (Demirel & Danisman, 2019).

Varadarajan (2017) emphasizes that at the product level, an environmental innovation consists in the introduction of a new or improved product which environmental impact is significantly lower. At the process level, Klewitz & Hansen (2014) argue that environmental innovation is associated with redesign of operations aiming to produce goods or services using less resources, hazardous materials, and improving the eco-efficiency associated to production activities.

On another hand, organizational environmental innovation generally is associated with formalized management systems such as environmental management systems (e.g. ISO 14001 or EMAS), and tools such as environmental policies, environmental management accounting, stakeholder management, sustainability vision, codes of conduct, employee engagement in sustainability or CSR activities, as well as organizational structures (Klewitz & Hansen, 2014).

Open collaboration

Since the first publication of Chesbrough (2003) a decade and a half ago, the attention of academics, companies, and policy makers on the open collaboration or open innovation paradigm has growing fast (Bogers, Chesbrough, & Moedas, 2018). Open innovation refers to "the use of purposive inflows and outflows of knowledge to accelerate internal innovation" (Chesbrough, 2006, p.1). This knowledge exchange aims to perform successful collaborations with external players such as suppliers, customers, universities, research centers, other companies, and competitors (Guertler, Michailidou, & Lindemann, 2016).

Literature on openness suggests that there are three core modes of open innovation: inbound or outside-in innovation, outbound or inside-out innovation, and coupled innovation (Kessler, 2013). Inbound innovation, refers to the way in which companies can integrate external available knowledge and ideas, aiming to improve their innovativeness capacity (Kessler, 2013), and is based on the enriching of the company's own knowledge base through the integration of suppliers, customers, and external knowledge sourcing (Enkel, Gassmann, & Chesbrough, 2009).

Acquisition and integration of knowledge also can be fostered by using "rich media, face-to-face meeting, staff exchange and joint supervision of knowledge transfer process, as well as by adopting dedicated ICT systems, promoting videoconferences and providing project management tools" (Natalicchio et al., 2017, p.1369). However, a successful external knowledge integration requires developing a critical level of absorptive capacity to learn effectively from external knowledge sources (Natalicchio et al., 2017).

On the other hand, the outbound innovation or inside-out process refers to the way in which internal knowledge is transferred outside the companies' boundaries (Kessler, 2013). Whereas the inbound process is based on the absorptive capacity, outbound innovation is supported in the desorptive capacity, which implies identifying external opportunities to transfer knowledge to the recipient (Natalicchio et al., 2017; p.1370).

Finally, the coupled open innovation process "deals with the joint use of knowledge by different organizations to innovate, thus concurrently involving inflows and outflows of knowledge" (Natalicchio et al., 2017, p.1370). The coupled process is based on the co-creation with complementary partners through cooperation activities, alliances, and joint ventures, in which success depends of giving and receiving (Enkel et al., 2009; Greco, Grimaldi, & Cricelli, 2015).

Adopting an open approach is not always easy. Prior literature suggests that the main barriers that declare the companies are related to the lack of information about market or the fact that they do not need to innovate (Ricez-Battesti, & Petrella, 2013). Furthermore, the implementation of open innovation is a big challenge for companies since establishing partnerships is a time-consuming issue that represents a transaction cost because of the use of external knowledge sources and intellectual property (Huizingh, 2011).

Digital Technologies and Open Collaboration for Environmental Innovation

Industries are required to improve their environmental efficiency to generate financial and market value (Jakhar, Mangla, Luthra, & Kusi-Sarpong, 2018). In doing so, industries must involve to a set of different primary and secondary stakeholders, as well as economic and social stakeholders, in order to collaborate and work to develop and enable a circular flow of efficient materials and resources (Jakhar et al., 2018).

Collaboration improves workforce flexibility, improves product performance and can lead to the design of efficient waste reduction strategies, while promoting the development of more sustainable business models, thus helping to make societies more sustainable (Witjes &

Lozano, 2016). Some of the most significant modes of collaboration in an environmental innovation context are: crowdsourcing (inbound), customer co-development (coupled mode), and R&D alliances (coupled mode). In this section, we summarize the role of digital technologies in different modes of collaboration in an environmental innovation context (table 1).

Crowdsourcing

In recent years, crowdsourcing has received extensive attention from academics and professionals (Meng, Hang, & Chen, 2019; Ruiz, Brion, & Parmentier, 2020; Simula & Ahola, 2014). The above, considering that the digital age offers a great opportunity for companies to access new knowledge for innovation processes (de Mattos, Kissimoto, & Laurindo, 2018; Han, Sun, Song, Fang, & Liu, 2021; Ruiz et al., 2020). Specifically, in the last decade the use of crowdsourcing and open innovation approaches has increased to involve different actors in solving problems or in developing projects (Acar, 2019; Ruiz et al., 2020; Thompson & Bentzien, 2020). Indeed, previous studies (Vignieri, 2020) define crowdsourcing as a mode of open innovation, in the context of the collaborative economy. In this sense, different crowdsourcing configurations are identified in organizations: internal crowdsourcing; community crowdsourcing; open crowdsourcing; and crowdsourcing via a broker (Simula & Ahola, 2014)

Crowdsourcing allows improving the efficiency of innovation (Li, Bian, Liu, & Wu, 2020), democratize the innovative process, promote creativity and use external knowledge as a response to the challenges of the organization (Forbes, Han, & Schaefer, 2020). Furthermore, crowdsourcing as a new pattern of innovation allows companies to reduce risks and costs (Meng et al., 2019) and generate creative ideas through the interaction of different users (Acar, 2019; Cheng et al., 2020; Forbes et al., 2020; Seltzer & Mahmoudi, 2013).

Currently, crowdsourcing is a mechanism to generate a greater globalization in innovation sourcing, due to the growing competition in innovation and the importance of information technologies (Bakici, 2020). Through collaborative crowdsourcing communities, users become co-creators of new products (Liu, Du, Hong, Fan, & Wu, 2020) and access a set of

relevant knowledge (Pohlisch, 2020). In this regard, crowdsourcing is a topic of great interest in the literature (Campos-Blázquez, Morcillo, & Rubio-Andrada, 2020) and constitutes an open innovation practice widely used by companies (Pohlisch, 2020).

In the environmental innovation context, crowdsourcing is a useful mechanism through which potential "solvers" can generate solutions to important innovative challenges (Abbate et al., 2019). Crowdsourcing can take the form of open calls (Boons and Stam 2019) or can be performed through intermediary platforms (e.g. *InnoCentive*, *IdeaConnection*, or *Innoget*), in order to address environmental-oriented innovation challenges. Crowdsourcing makes it possible to gather opinions, ideas, drafts, suggestions and information from the general public, but it can also be aimed at specific crowds, such as customers. It is a particularly effective process in the early stages of an innovation process, because it allows to generate a large number of ideas (Van de Vrande & Rochemont, 2017)

Customer co-development

The traditional marketing paradigm, in which the customer assumed a passive role in the development of new products, has been challenged in recent years by a perspective in which customers actively participate in the process (O'Hern & Rindfleisch, 2010). Thus, it is increasingly common for companies to develop products jointly with customers (M Oinonen, Ritala, Jalkala, & Blomqvist, 2018). Consequently, in the context of collaborative innovation, co-creation processes with clients have attracted the attention of academics (Minna Oinonen, 2016) and managers, who must identify the objective of each stakeholder involved to improve co-creation (M Oinonen & Jalkala, 2015).

We use the term co-development or co-creation to refer to way in which organizations seek contact with end customers to test and validate new ideas and prototypes and to bring new ideas together to bring the product to market. Co-development can be perfectly a marketing strategy if managed properly, because it engages customers with their product (Van de Vrande & Rochemont, 2017). For Kazadi et al. (2015) co-development with stakeholders involves "collaborative activities during which multiple interdependent external stakeholders contribute to a firm's innovation process" (p.1).

Co-development is a coupled process of open innovation, initially applied to corporate innovation, with a special emphasis on investigating how it generates business value in the contexts of user-centric innovation and open source projects, virtual communities/platforms and multidisciplinary projects (Silva & Wright, 2019). In the context of environmental innovations, co-development is a way to share, combine and renew resources and capabilities between companies and active users in order to create value through new forms of interaction, and by combining resources, knowledge or ideas to make fundamental environmental changes in companies (Arnold, 2017).

Some activities to implement co-creation in the context of environmental innovation workshops (interactive meetings to generate solutions that result in innovative or incrementally changed products or services); web communities (virtual groups that take the form of social networks or other web applications to interact or improve product sustainability impacts); ideas competition (forums in which people interested in a topic generate creative ideas or concepts regarding a particular sustainability issue); dialogue (a tool to engage people in a serious discussion on a special topic (Arnold, 2017). Co-development processes are especially useful for interactions that take place during different phases of innovation, such as co-production (Lacoste, 2015).

Environmental R&D alliances

R&D alliances are innovation-based relationships formed by two or more partners who pool their resources in search of a common goal. R&D alliances are also known as cooperative alliances, technology alliances, strategic technology partnerships or technological cooperation agreements (Martínez-noya & Narula, 2018).

Alliances for innovation can be horizontal (between rivals), vertical (with suppliers or customers) or institutional (with universities). In horizontal alliances, usually cooperation is established between companies that carry out the same type of activity. Vertical alliances, generally are established between companies operating in related industries along the same value chain (Martínez-noya & Narula, 2018).

In the context of environmental innovations, an inter-firm alliance can be defined as "a voluntary cooperative agreement between firms aimed at the development, manufacture and/or distribution of green and sustainable products or services in which partners exchange, share or co-develop environmental resources, knowledge or technologies to create economic, environmental and/or knowledge value" (Niesten et al., 2020, p.4). Environmental alliances, for instance, can be performed with the objective to lower emissions or to solve specific challenges in the energy sector (Jakobsen, Lauvås, & Steinmo, 2019).

Table 1. The role of digital technologies in different modes of collaboration in an environmental innovation context.

Modes of collaboration	**Benefits in an environmental innovation lens**	**Digital technologies**
Crowdsourcing (inbound)	Improves the efficiency of innovation (Li et al., 2020) Democratizes the innovative process, promotes creativity and use external knowledge as a response to the challenges of the organization (Forbes et al., 2020) Allows companies to reduce risks and costs (Meng et al., 2019) Allows to generate creative ideas through the interaction of different users (Acar, 2019; Cheng et al., 2020; Forbes et al., 2020; Seltzer & Mahmoudi, 2013) Allows a greater globalization in innovation sourcing (Bakici, 2020) Makes users co-creators of new products (Liu et al., 2020) Allows access a set of relevant knowledge (Pohlisch, 2020)	Crowdsourcing communities Open calls Intermediary platforms
Co-development (coupled mode)	Affects the development of innovative services (Moghadamzadeh et al. 2020) Improves the performance of innovation (Goyal et al., 2020; Lau et al., 2010; Tsou et al., 2019)	Social media platforms Innovation workshops Web communities Ideas competition Dialogue

	Develops radical organizational creativity (Balau et al., 2020b) Develops business intelligence (Fagerstrøm et al., 2020) Allows to share, combine and renew resources and capabilities between companies and active users (Arnold, 2017)	
R&D alliances (coupled mode)	Produces products under the 'brand' of the environmental group Contributes to specific environmental or fundraising activities Helps to differentiate products and position companies as "green" Develops green and economically viable solutions implements economically viable environmental programs for the greening of business practices investigates environmental scientific and economic issues and propose government policies (Hartman & Stafford, 1997)	Interchange of resources, knowledge or technologies to create economic, environmental and/or knowledge value enabled by digital technology

Source: Own elaboration based on literature.

Conclusion

This chapter has discussed how digital technologies promote open collaboration processes to achieve environmental innovations. As Luers et al. (2020) assert, there are currently two main streams that are conditioning the future of humanity: climate change and digital revolution. Digital platforms, macrodata, and artificial intelligence present important opportunities to drive social transformation and to achieve a secure, climate-smart world. This is due to the great capacity of digital technologies to transform societies, cultures and economies. Digital technologies in the context of sustainability are encouraging environmental attitudes and behaviors, collective climate actions, and changing the way business is done (Luers et al., 2020).

Digital technologies are facilitating collaborative innovation by becoming a means to provide new types of products and services with environmental benefits. For that reason, companies now need to review their inter-firm collaboration and coordination models to meet the expectations of strategic or potential customers. In the context of environmental innovation,

for example, it is much more necessary to establish governance structures and mechanisms capable of reconciling the points of divergence between allies (Q. He, Meadows, Angwin, Gomes, & Child, 2020).

Digital technologies will also make clients more deeply involved in co-creation processes through information and communication technologies. Blockchain, for example, is considered a promising medium for transactions between companies and will therefore improve collaboration between them. Industry 4.0, on the other hand, has great potential to impact global value chains and reduce the use of intermediaries. Likewise, digital transformation will generate new networking possibilities, facilitating cooperation between different actors (Q. He et al., 2020).

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Publication II

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Towards a comprehensive framework to analyse the benefits of openness for sustainability-oriented innovation: A systematic literature review

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Towards a comprehensive framework to analyse the benefits of openness for sustainability-oriented innovation: A systematic literature review

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Abstract

This study systematically reviews the scientific literature on the role of open innovation in addressing current and emerging societal and environmental challenges. To do so, we analysed the *what*, *how*, *who* and *why* of integrating external partners for sustainability purposes. We found a clear predominance of open innovation mechanisms to develop environmental innovations rather than innovations focused on a triple bottom line. We identified at least four mechanisms associated with the *inbound* mode of open innovation (crowdsourcing, lead-user workshops, intermediation, and experiments and discussion sessions) and 10 mechanisms related to the *coupled* mode of open innovation (alliance, business-non-profit engagement, co-creation, joint ventures, cooperation, collaborative innovation contests, coopetition, cross-sector partnerships, joint development projects, and innovation networks). Even though sustainability-oriented innovation promises to be a source of societal transformation and entrepreneurial opportunities, we found that firms can face some tensions when simultaneously addressing financial, environmental and social purposes.

KEYWORDS
collaborative innovation, environmental innovation, open innovation, sustainability-oriented innovation, sustainable business, sustainable innovation

1 | INTRODUCTION

The 2030 Agenda and its 17 Sustainable Development Goals (SDGs) are being adopted by firms in order to help resolve such major societal challenges as poverty, inequality, migration, violence, air pollution, health crises, water scarcity, waste management, and climate change (Adams et al., 2016; Silvestre & Ţîrcă, 2019), to mention just a few examples. Those sustainability issues, due to their high level of complexity (Porter & Birdi, 2018), require system-level changes that may be addressed by firms from an innovation-centred perspective (Klewitz & Hansen, 2014), that is, from the lens of sustainability-oriented innovation (SOI).

SOI consists of developing new or improved products and creating new processes that introduce benefits to the environment and society (Geradts & Bocken, 2019). Compared with most traditional ones, this type of innovation has a higher degree of complexity, uncertainty and unpredictable financial returns for the firms, making the innovation process more challenging (Kennedy et al., 2017; Kralisch et al., 2018).

In that regard, an effective response to the challenges of developing new sustainability-oriented products or processes entails

companies engaging with external partners to co-develop new and viable sustainable solutions. This approach, called open innovation, 'describes a purposive attempt to draw together knowledge from different contributors to develop and exploit innovation' (Ahn et al., 2019, p. 1). For instance, numerous opportunities to create, exchange and capture business value are being facilitated via collaboration and crowdsourcing processes, bringing together firms and industrial actors, policymakers, academicians, scientists, and citizens that are willing to define and apply responses to sustainability issues, such as local climate solutions (Elia et al., 2020).

Collaboration has been a critical mechanism for creating innovative solutions to address such issues as water scarcity management (Porter & Birdi, 2018), climate-smart agricultural production (Yamoah et al., 2020), and the co-identification and co-exploitation of sustainable business opportunities (De Silva & Wright, 2019). The Covid-19 pandemic, for instance, increased the development of joint innovations among large companies, start-ups, governments, universities, and research centres, in the hope of protecting people and saving lives. Innovative approaches against Covid-19 have included, for instance, calls for research proposals, ideation processes, joint development of technological devices, and collaborative research and data sharing (OECD, 2020).

Although the literature on corporate sustainability and innovation management has provided clear evidence that: (1) the relationship between open innovation and SOI is fast becoming a key topic (Ahn et al., 2019; Reficco et al., 2018; Slotegraaf, 2012; Von Geibler et al., 2019); (2) the integration of partners in the innovation process is a crucial capability to advance towards SOI (Hansen & Grosse-Dunker, 2012); (3) firms can benefit from open innovation to obtain the proper knowledge to develop new sustainable products, processes or businesses models (Kennedy et al., 2017); and (4) firms collaborating with external actors are more likely to create new or improved products that achieve market success (Melander, 2017), few studies have identified and summarised the mechanisms that occur in open innovation initiatives oriented towards a sustainability purpose.

Some of the existing systematic reviews summarise the knowledge on multi-sector alliances for sustainability (Gray & Stites, 2012), the motivations to collaborate through environmental alliances (Niesten et al., 2020), the collaboration mechanisms involved in environmental or sustainable supply chain management (Cloutier et al., 2019), the success factors involved in environmental product innovation (Fleith de Medeiros et al., 2014), and the reasons why collaborative innovations sometimes fail (Porter & Birdi, 2018).

We build upon those reviews by analysing the scientific literature on the role of openness in addressing innovations to solve current and emerging societal and environmental challenges. We analysed 35 scientific publications that were carefully selected based on predefined criteria, to explain how a set of open innovation approaches can lead to the achievement of different outcomes in the context of SOI (Ordonez-ponce et al., 2020).

Aligned with the goal of this special issue to provide a better understanding of how systemic changes in our societies may have an impact on sustainability as well as the urgent need to take action to solve societal changes by implementing innovative solutions in every sphere of our society (Zilahy & Dobers, 2021), this paper sheds light on the role of the open innovation model as a conceptual basis to examine the collaborative side of new business solutions that place social and environmental concerns at the core.

In that sense, in this study, we propose a comprehensive conceptual framework to provide clarity on the new solutions aimed at tackling societal challenges and the mechanisms used to collaboratively address sustainability issues, as well as the barriers and success factors, variety of partners, and the reasons and motivations of companies to address the most urgent sustainability-related matters. This study also contributes to the debate on incremental improvements and systemic transformations towards sustainability transitions on the basis that collaborative SOI processes can sometimes lead only to incremental improvements that are not adequate to promote real impacts at the system or society level.

We posed the following research questions to guide this systematic literature review: (1) What sustainability goals are pursued through open innovation approaches? (*the what*) (2) How are partners integrated, that is, what open innovation mechanisms are being considered and discussed in the SOI literature? (*the how*) (3) Which secondary stakeholders are integrated into collaborations to achieve sustainability-oriented innovations? (*the who*) (4) Why do companies and external actors set up collaborations to innovate with a sustainability purpose? (*the why*).

2 | CONCEPTUAL BACKGROUND OF THE STUDY

2.1 | Sustainability-oriented innovation

Sustainability-oriented innovation is an umbrella term often interchangeable with sustainability-driven/related innovation or sustainability/sustainable innovation (Buhl et al., 2019). Research on sustainability-oriented innovation has focused mainly on innovations with a strong emphasis on environmental aspects (Adams et al., 2016) in addition to financial concerns. However, the discourse on sustainability has evolved to include the social and environmental impacts at the same time (Klewitz & Hansen, 2014; Silvestre & Ţîrcă, 2019).

Numerous frameworks have been proposed for the classification of SOI. Research in this field typically establishes typologies considering 'whether an innovation is incremental or radical, whether it focuses on processes or products, and whether it is new to the organisation, or to the industry, or to the world' (Silvestre & Ţîrcă, 2019, p. 326). For instance, Inigo et al. (2020) evaluated two main dimensions of SOI: incremental and radical. The first involves minor variations in innovation processes and is based on marginal changes, such as the improvement of existing products' materials or energy efficiency. In contrast, radical innovation entails transformative changes involving the development of new products, the design of new markets or finding new ways to cater for existing markets (Inigo et al., 2020; Lin, 2019).

Varadarajan (2017) also proposed a framework for SOI consisting of three types of innovation (business model, product-service system, and technological), three sustainability effects (ecological, social, and economic) and three life-cycle-stages (manufacture, use, and end-of-life). Similarly, Klewitz and Hansen (2014) developed an SOI proposal that includes a taxonomy of sustainability strategies (resistant, reactive, anticipatory, innovation-based, and sustainability-rooted) and a set of SOI practices and types of innovation. The study by Adams et al. (2016) is another notable work proposing a conceptual framework to analyse the innovation activities that firms engage in to become more sustainable. In that conceptual model, Adams et al. (2016) distinguish between three stages in the context of SOI: operational optimisation (doing more with less), organisational transformation (doing good by doing new things), and system building (doing good by doing new things with others).

2.2 | Open innovation

Open innovation is a widely used concept in academia, business and innovation policy that has emerged to explain how companies can use internal and external ideas and leverage knowledge inputs and outputs to make innovation processes more successful (Bogers et al., 2018). In addition, open innovation is a crucial perspective for theorising about, analysing and exploring how external partners can provide valuable ideas, knowledge and resources to boost firm innovation (Filiou, 2020).

The literature on open innovation claims that the flow of knowledge between an organisation and external actors may involve innovation activities to benefit from knowledge from external sources (inbound); innovation activities that aim to insert internal ideas into the market (outbound); or a combination of inbound and outbound activities, known as the 'coupled mode,' in which firms and partners jointly develop or commercialise innovations (Flor et al., 2019; Mazzola et al., 2012).

For instance, a typical mechanism of the inbound mode is crowdsourcing, a participative activity in the form of an open call by a company to ask a group of individuals to provide ideas regarding a specific challenge (Porter et al., 2020). The success of crowdsourcing depends on both the number of submitted ideas and the quality thereof (Schäper et al., 2020). Regarding the outbound mode, one usual process is corporate business incubation, which is aimed at 'developing potentially profitable ideas and offering supportive environments for entrepreneurs inside the organisation to identify novel paths to market' (Chesbrough & Brunswicker, 2014, p. 20).

In the coupled mode, innovation networks are one of the most effective collaboration mechanisms, made up of firms and a broad set of partners, such as clients, suppliers, universities, non-profit organisations and communities, among other actors, with the intention being to promote the dissemination and exchange of knowledge in order to address a specific challenge (Peterman et al., 2020).

In the context of sustainability-oriented innovation, Inigo et al. (2020) indicate that the coupled mode of openness is a feasible way to improve SOI since firms can benefit from active partners engagement. However, as Huizingh (2011) suggests, firms need to determine on a first basis with whom and for what purpose they should collaborate. In that regard, previous studies have proposed different ways to classify partners to collaborate. For instance, from the firm's perspective, stakeholders can be categorised as internal and external (Mart et al., 2016). In that sense, for the purposes of this study, external stakeholders are 'those who are outside organisational boundaries (thus excluding employees) and do not have ownership of the firm in any way (thus excluding owners, investors and shareholders)' (Ghassim, 2018, p. 16).

External partners can help generate innovations or exploit the solutions that the company has developed. Those collaborations can be of different lengths, involve varied individuals or organisations, have diverse initiators, and may imply different motivations for partners (Huizingh, 2011). In an open innovation context, each partner must be clear about its role, responsibilities and expectations within the collaboration process (Porter & Birdi, 2018). A successful open innovation process also requires partners to have clear reasons to collaborate.

According to the resource-based view of the firm, organisations collaborate to access their partners' complementary resources, such as information, knowledge, capabilities, technology, or production and distribution capacities, while the resource dependence theory suggests that firms pursue access to those resources to cope with uncertainty and respond faster to changes in industries and markets. Meanwhile, the institutional theory suggests that through collaboration, individuals or organisations gain reputation and legitimacy among their allies. Finally, the transaction cost theory claims that reducing and sharing transaction costs is a strong motivator for inter-organisational collaborations (Niesten et al., 2020).

3 | METHODOLOGY

3.1 | Research design

We performed a systematic literature review (SLR) to address our research questions. An SLR is a research design for synthesising data that is already published, based on a systematic and pre-defined process (Kraus & Dasí-Rodríguez, 2020; Lopes & de Carvalho, 2018). Systematic literature reviews help to consolidate a field of knowledge and allow researchers to take stock of published scientific literature and derive new conceptualisations and future research guidelines (Breslin et al., 2020).

We conducted a descriptive analysis of the articles included in this review. We also performed a content analysis of the studies based on a *what-how-who-why* framework in order to determine the relationship between open innovation and SOI and to establish a conceptual integration of multiple literature streams (Jaakkola, 2020). To systematise the data, we designed a codebook (see Appendix A) to describe each article (e.g., level of analysis, source of information, theoretical perspective, among others), as well as the main categories (see Appendix B) related to our four research questions (the

TABLE 1 Inclusion and exclusion criteria

N°	Criteria	Inclusion	Extended inclusion criteria	Exclusion
1	Time frame	Published between 2000 and 2021.	To cover the last two decades of research.	Any other year.
2	Type of document	Peer-reviewed articles.	Selected peer-reviewed articles because wanted to ensure quality.	Books, book chapters, conference proceedings, reports, editorials, translations, and other types of material.
3	Language	Studies must be in English.	To avoid restrictions related to language.	Any other language.
4	Study type	Empirical studies.	Since we are interested in the empirical evidence around our research topic.	Studies that do not report empirical findings, such as theoretical or conceptual studies.
5	Focal firm	At least one focal firm.	Since we are interested in collaborations that include companies.	No firms involved.
6	Thematic fit	Clear relationship between open innovation and SOI.	Articles must refer to any type or mode of collaboration that leads to an SOI.	Collaboration for SOI is not a central theme. Openness or sustainability terms are used with a different meaning. Articles refer only to the likelihood or propensity of introducing any type of innovation. Articles that do not report an active role of the partners in the collaboration process (e.g., articles only based on patent statistics, or firm alliance data).

sustainability goal, the partners involved, the open innovation mechanisms, and the reasons to collaborate). We followed a deductive logic to reflect collaboration patterns in an SOI context (Jakobsen et al., 2019; Neutzling et al., 2018). In this section, we explain the stages to identify and synthesise our sample of research articles, as proposed by Parmigiani and King (2019).

3.2 | Search

To identify the publications that were analysed in this systematic review, we used the following keyword combinations: ('sustainab* innovation' OR 'innovation for sustainability' OR 'sustainability-oriented innovation' OR 'sustainability-driv* innovation' OR 'sustainability-related innovation' OR 'eco-innovation' OR 'ecological innovation' OR 'environmental innovation' OR 'green innovation') AND ('open innovation' OR 'openness' OR 'collaborat*' OR 'alliance*' OR 'co-innovation' OR 'cooperat*' OR 'partnership*'). Truncation symbols were used to retrieve variant spellings, synonyms and related terms, and word endings. The search was performed in the Web of Science (WoS) — Core Collection database since WoS is considered the most rigorous and comprehensive research publication database (Iñigo & Albareda, 2016; Melander, 2017; Porter & Birdi, 2018). The period of included papers was 2000–2021. The searching process took place in March 2021 and was later updated in January 2022.

Following previous systematic literature reviews, we searched the combination of terms in the publications' titles, abstracts, and keywords. For instance, Klewitz and Hansen (2014), in a systematic literature review (SLR) about sustainability-oriented innovation, searched the literature in the titles, abstracts and keywords of the records to improve the probability of finding relevant studies. A similar strategy was used in previous SLRs developed in the fields of innovation (Cinar et al., 2019; West & Bogers, 2014) and sustainability-oriented labs (McCrory et al., 2020).

3.3 | Eligibility assessment

Studies included in the review fulfilled the attributes described in Table 1.

Based on the search equation, we initially retrieved 569 publications. After applying the timeframe, document type, and language filters, we kept 512 articles which were imported to Mendeley. The next step was to screen the titles, abstracts, and keywords of those articles. At this stage, we aimed to determine whether the documents were related to our research goal or not. Specifically, we analysed whether each study addressed the collaboration between enterprises and external actors for SOI.

Articles for which the reading of these fields did not lead to a conclusive decision were analysed in full text. 139 articles were included in this step. After that, all full-text articles were examined for eligibility in our review. We verified that the articles met all the inclusion criteria in that step. Finally, 35 scientific articles were included in the systematic review. We were very strict in selecting the final sample of articles since we were looking for publications connecting open innovation and SOI. The whole process is shown in Figure 1.

3.4 | Data extraction and synthesis

The 35 articles included in this review were analysed following the procedure used by Klewitz and Hansen (2014) and Govindan et al.

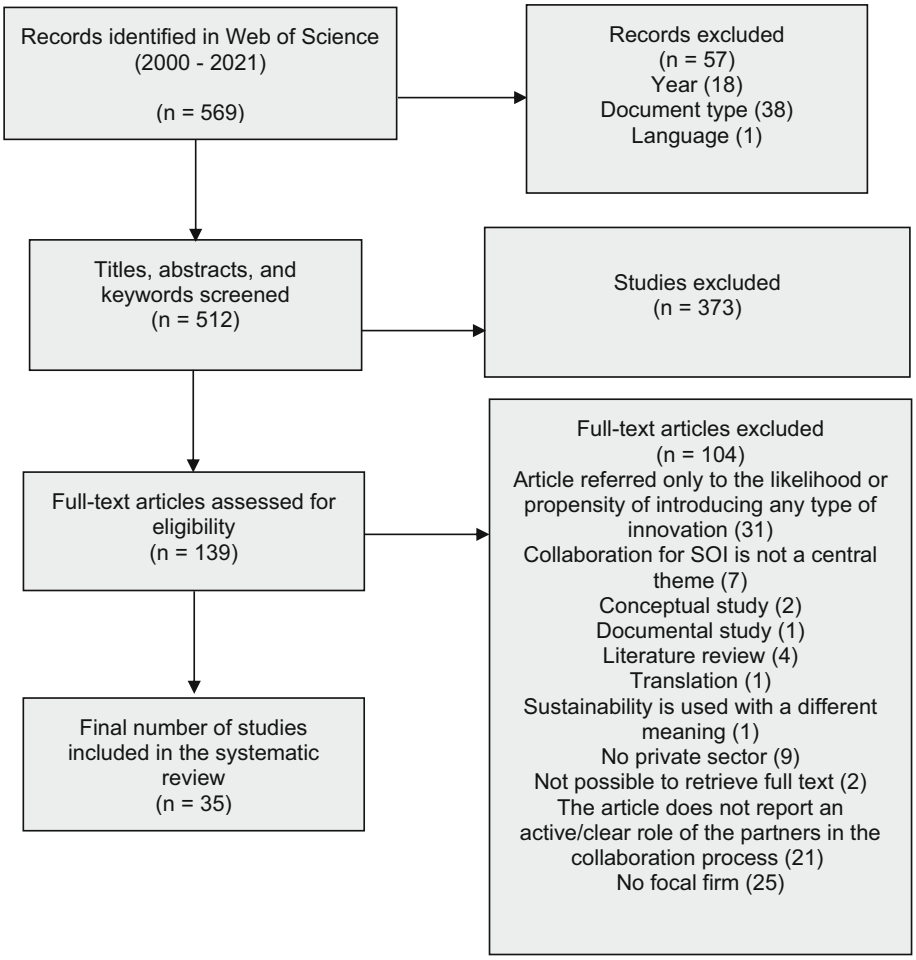

FIGURE 1 Systematic literature review flow diagram.

(2021). First, we conducted a descriptive analysis of the publications. Second, we performed a content analysis of the articles, using categories identified in our background and terminology section, and related to the review questions. To do this, we exported the articles to ATLAS.ti and applied code schemas to analyse each one. The in-depth analysis of the articles made it possible to identify the topics related to our four-dimensional structure (the *what*, *how*, *who* and *why*).

4 | RESULTS

4.1 | Descriptive analysis

In this section, we present an outline of the main features of the articles discussed in this review. We found that 13 of the total articles included in this review are addressed from the perspective of the firm (organisational level of analysis); 11 are focused on the project perspective (intra-organisational level of analysis), while 11 are approached from an inter-organisational level of analysis, including innovation networks, coopetitive relationships, and alliances. Diversity in the levels of analysis and research objects evidence the multilevel nature of SOI.

From a methodological point of view, 34 of the articles analysed are based on qualitative perspectives (22 multiple case studies and 12 single case studies), and only one article used mixed methods. These results are closely related to the findings of Aka (2019), which argues that in research describing processes, qualitative strategies are beneficial for exploring emerging or less understood phenomena. We also identified the main theoretical perspectives or conceptual frameworks on which the analysed studies were based. For instance, we found that the stakeholder theory, the industrial ecology perspective, the network theory, and the absorptive capacity framework are the most widely used perspectives by the authors included in this review.

4.2 | Content analysis

4.2.1 | Sustainability orientation

The studies we analysed deal mainly with the environmental dimension of sustainability (24 articles), while two articles were focused on open innovation processes whose emphasis is only on the social sphere. Nine studies addressed environmental and social sustainability goals, mainly related to collaborative approaches that directly sought both the development of an innovation that simultaneously had social and environmental impacts (Table 2). We found a predominance of open innovation mechanisms to develop environmental innovations. However, authors such as Veleva and Bodkin (2018) argue that it

TABLE 2 Sustainability orientation of the studies

Sustainability orientation	Sustainability innovation goal	Authors
Triple Bottom Line dimension This is the dimension where the foundations are environmental, social, and financial goals (Veleva & Bodkin, 2018).	Eco design and green marketing; new product development for smaller impacts on the environment and new product lines (education and health). New products that have less environmentally harmful inputs and impact and concepts for sustainability communication; health and change management. Development of smart products to improve the quality of living of elderly people. Affordable and comfortable housing for low-income families who want to own their home. Using low carbon emission vehicles to provide micro-entrepreneurship opportunities to the unemployed. Reducing youth unemployment through a new retail business model. Product improves health and safety of employees and other stakeholders. Mobility services aimed to lower greenhouse gas emissions and air pollution, at the time that social value is created in the form of more room for children and outdoor activities, increase of jobs, as well as safer and more enjoyable rides for passengers. Ideation processes to develop circular economy and energy efficiency solutions, social innovation, and sustainable organisational initiatives.	***n* = 9** Lopes et al. (2017); Klewitz (2017); Behnam et al. (2018); Goodman et al. (2017); Juntunen et al. (2019) Watson et al. (2020); Stal et al. (2021); Munten et al. (2021); Greco et al. (2021).
Social dimension The social dimension is about paying attention to human capital development, job creation, and safety issues, among others (Saunila et al., 2018).	Innovations focused on economic development, ecosystems, education, healthcare, and human rights. Development of a non-pharmaceutical method to treat a mental condition that mainly affects children. Delivering medical supplies to remote areas and exploring long-term viable ways to enter those emerging markets.	***n* = 2** Mirvis et al. (2016); Kazadi et al. (2016).
Environmental dimension The environmental dimension encompasses factors such as land use, waste handling, hygiene, and energy and water consumption (Saunila et al., 2018).	New product with components that are not harmful to the environment. Development of products made for more environmentally friendly usage. Sharing of best environmental practices, joint environmental monitoring and production planning. Solve specific challenges in the energy sector and pursue environmental improvements and pollution reduction. New process for product reuse, remanufacturing and waste repurposing. New sustainable product in the field of food; sustainable packaging. Generating clean energy without producing waste, pollution and greenhouse emissions. Gathering and disseminating information to foster eco-innovation. New platforms for the measurement, evaluation and showcasing of eco-innovations. New materials and alternative business models for making improvements to environmental products. New solutions in energy, water technologies, biofuels, and management practices. New organisational forms to firms transitioning towards the circular economy (circular business model innovation).	***n* = 24** Melander and Pazirandeh (2019); Aka (2019); Reficco et al. (2018); Jakobsen et al. (2019); Veleva and Bodkin (2018); Melander (2018); Zimmerling et al. (2017); Arnold (2017); Fliaster and Kolloch (2017); Lee and Kim (2011), Wadin et al. (2017); Neutzling et al. (2018); Rossignoli and Lionzo (2018); Kennedy et al. (2017); Kanda et al. (2018); Bocken et al. (2014); Brown et al. (2019); Pucci et al. (2020); Todeschini et al. (2020); Kanda et al. (2018); Mousavi and Bossink (2020); Pace and Miles (2020); Zucchella et al. (2021); Siltaloppi and Jahi (2021).

needs to be clarified how addressing environmental impacts can be coordinated with social and community impacts.

Another challenge in the study of environmental innovations is that, in some cases, it is difficult to determine the actual impact of those innovations on the sustainability performance of the firm, which in turns prompts the need to develop systems for measuring and monitoring the scope of those innovations in the long term (Goodman et al., 2017). For instance, in terms of impact measurement of environmental benefits, an innovation can be measured based on its outcomes or on the intended environmental impacts of the innovation solutions (the objective or intention) (Kanda et al., 2018).

Silvestre and Ţîrcă (2019) point out that sustainability-oriented innovations should balance environmental, social, and economic purposes. In practise, however, companies appear to have difficulties when simultaneously addressing environmental and social purposes. Also, the problem of clarifying precisely what sustainable innovation means demonstrates that 'the field continues to lack a common theoretical framework that encompasses the distinct aspects of SI' (Iñigo & Albareda, 2016, p. 2).

However, what is evident is that SOI claims for a triple-bottom-line perspective in which sustainability is a core concern of the business model, moving from an instrumental perspective where profit is the dominant motivation to a more integrative approach to sustainability (Munten et al., 2021). Additionally, there is a consensus that SOI cannot be approached by individual actors alone, given that searching for innovative solutions for sustainability challenges requires collaboration within the firms and between the firms and other actors (Munten et al., 2021).

Even though SOI promises to be a source of social transformation and entrepreneurial opportunities, the search for a financial, social, and environmental balance can generate tensions within the firms or unintended negative consequences. For example, according to Munten et al. (2021), some positive outcomes at any given level can negatively affect other levels. It happens, for example, when improvements in a product's eco-efficiency cause an increase in its demand.

In that same vein, Stal et al. (2021) claim that the search for business model innovations for sustainability presents inherent contradictions derived from the efforts of the companies to integrate environmental, social, and economic objectives at the same time. The contradictions arise because those three objectives, despite being interdependent, have different natures: economic value creation seeks to satisfy the market's demands, environmental value is focused on the needs of complex biophysical systems, and social value attends to those human needs that the markets fail to satisfy (Stal et al., 2021).

In cross-sector partnerships for sustainable business model innovation, some challenges and tensions arise because the partners can create value in different ways and prioritise different interests (Stal et al., 2021). For example, some tensions arise because the private sector generally responds to the market logic, while the public sector instead responds to bureaucratic logic. Furthermore, although the market logic tries to align with social and environmental value creation, customers and market efficiency usually are prioritised (Stal et al., 2021).

In the case of mechanisms such as coopetition, referring to the simultaneous pursuit of cooperation and competition between actors in a value network, Munten et al. (2021) reported that this form of collaboration could generate tensions in at least four dimensions: value generation, temporal articulation, relational evolution, and knowledge circulation. For example, in value creation, some tensions can arise because the actors expect to generate sustainable value by considering social and environmental factors whilst they pursue their own economic ambitions (Munten et al., 2021).

The other three categories identified by Munten et al. (2021) are temporal articulation tensions that arise because the actors need separated positions to benefit from SOI in the short term, but at the same time, they must develop an integrative perspective in the long term to promote the impact of SOI on a system level; relational evolution tensions, which emerge principally due to the unequal access to the benefits generated by the exploitation of SOI opportunities; and finally, there are knowledge circulation tensions, caused by the need of the actors to share technical knowledge whilst simultaneously protecting the knowledge they need (Munten et al., 2021). In summary, the role of tensions and paradoxes in the context of SOI could be a relevant research avenue since companies can use that framework to analyse and measure the results of their coopetitive relationships, as well as to identify ways to resolve those tensions (Munten et al., 2021).

4.2.2 | Open innovation mechanisms

This review also explored ways of collaborating for sustainable innovation. The studies analysed in this review mainly describe the inbound or coupled modes. These results are consistent with the traditional literature on open innovation, which points out that the inbound and coupled modes of open innovation are more common in practise and have received privileged treatment among researchers in that field (Culpan, 2014; Dahlander & Piezunka, 2014).

Table 3 shows at least four mechanisms associated with the inbound mode. These include crowdsourcing, a form of public call to collect new ideas or validate existing ones. For example, the study by Zimmerling et al. (2017) describes the use of a public call via different media in order to collectively and collaboratively discuss ideas about new products to improve the quality of living of people with physical limitations. Intermediation was another form of open innovation highlighted in the studies by Kanda et al. (2018) and Kanda et al. (2020). That mechanism is focused on scanning, gathering, and disseminating information, led by cities, technology transfer offices, platforms, architects, industry associations or other innovation ecosystem actors.

Since we selected articles describing collaborative processes in which partners played an active role, we recovered a more significant number of studies focused on the coupled mode. In this form of open innovation based on the creation or joint development of innovations, the most frequent form of collaboration were partnerships and joint development projects. Partnerships are the most traditional form of collaboration and have been addressed by different disciplines, such as management, international business, and innovation (Martínez-noya & Narula, 2018).

Wadin et al. (2017) reveal that competitors sometimes cooperate in alliances to achieve innovation faster and at a lower cost and risk. Moreover, joint development projects are often shorter collaborative programmes aimed at achieving precise, measurable results, which demand a high degree of interaction and commitment between the parties involved (Goodman et al., 2017). A similar mechanism identified in our study, which may imply a lower degree of commitment, was co-creation; co-creation processes are 'collaborative activities during which multiple interdependent external stakeholders contribute to a firm's innovation process' (Kazadi et al., 2016, p. 525). Some stakeholders are included through this mechanism by following a highly selective integration process (Arnold, 2017).

Table 3 also shows, for example, that crowdsourcing is a commonly used mechanism for environmental and triple bottom line contexts. In the same line, we found that other inbound mechanisms such as lead-user workshops, intermediation, experiments, and discussion sessions are associated with open innovation processes that pursue a

TABLE 3 Open innovation mechanisms

Open innovation mode	Mechanisms/practices	Environmental	Social	TBL	Authors
Inbound (sourcing)	Crowdsourcing	√→	√→	√→	Lopes et al. (2017); Zimmerling et al. (2017)
	Lead-user workshops	√→			Zimmerling et al. (2017)
	Intermediation	√→			Kanda et al. (2018); Kanda et al. (2020).
	Experiments and discussion sessions	√→			Bocken et al. (2014).
Coupled (shared activity)	Alliances	√→			Wadin et al. (2017); Kennedy et al. (2017); Veleva and Bodkin (2018); Jakobsen et al. (2019); Pace and Miles (2020).
	Business-nonprofit engagement	√→	√→	√→	Mousavi and Bossink (2020); Watson et al. (2020).
	Co-creation	√→	√→		Mirvis et al. (2016); Arnold (2017); Kazadi et al. (2016); Pucci et al. (2020).
	Collaborative innovation contests			√→	Greco et al. (2021).
	Coopetition			√→	Munten et al. (2021).
	Joint-ventures		√→		Mirvis et al. (2016).
	Cooperation		√→		Mirvis et al. (2016f).
	Cross- sector partnerships	√→		√→	Reficco et al. (2018); Stal et al. (2021).
	Joint development projects	√→		√→	Melander (2018); Behnam et al. (2018); Fliaster and Kolloch (2017); Lee and Kim (2011); Neutzling et al. (2018); Goodman et al. (2017); Todeschini et al. (2020).
	Innovation networks	√→		√→	Aka (2019); Melander and Pazirandeh (2019); Klewitz (2017); Rossignoli and Lionzo (2018); Juntunen et al. (2019); Brown et al. (2019); Zucchella et al. (2021); Siltaloppi and Jahi (2021).

purely environmental purpose. Regarding the coupled mode, we found that alliances, despite being very frequent in the studies analysed, are more approached in the context of environmental innovations. Regarding innovation solutions oriented to solve the three types of sustainability orientations simultaneously (triple bottom line), the most frequent mechanisms are collaborative innovation contests, coopetition, cross-sector partnerships, joint development projects, and innovation networks.

We found that inbound mechanisms such as crowdsourcing are often used with suppliers, customers, and users, while intermediation more commonly involves suppliers, customers, other firms, and industry associations (Table 4). In the coupled mode (Table 5), alliances, for example, usually involve collaborations with other companies, industry associations and higher education institutions, while co-creation, joint development projects and innovation networks are the open innovation mechanisms that involve the widest variety of partners.

4.2.3 | Collaboration partners

The partners identified in this systematic review range from suppliers, commercial research institutes, customers, competitors, other businesses, government, higher education institutions, private non-profit organisations, and communities. In Table 6, we show the number of articles in which firms collaborate with other partners to achieve an environmental, social and/or a triple bottom line goal. We found that in collaborative initiatives that pursue an environmental purpose, it is very common to collaborate with other companies, customers, and suppliers.

Our results coincide with previous studies showing that firms collaborate extensively with customers and suppliers for environmental innovations (Melander & Pazirandeh, 2019). The most frequent partners in collaborative processes oriented towards a purely social purpose are private non-profit organisations. This is not surprising given that NGOs, by nature, are oriented towards social ends and accumulate knowledge about challenges related to social equity. Private non-profit organisations are also important partners in collaborations that pursue both social and environmental goals together with customers and other firms.

In general, few collaborative processes involve key players such as competitors or communities. It is also important to note that most studies address collaborative processes involving a diverse number of actors, showing that partners and stakeholders integrated in different combinations and are not necessarily limited to traditional partners (Juntunen et al., 2019). However, incorporating many partners is not

TABLE 4 Relationship between partners and inbound mechanisms

Type of partner/inbound mechanisms	Crowdsourcing	Lead-user workshops	Experiments and discussion sessions	Intermediation
Suppliers	√→		√→	√→
Customers	√→	√→	√→	√→
Users	√→	√→		
Competitors				
Other firms			√→	√→
Industry associations			√→	√→
Producers				
Professional experts				
Agencies				
Government				
Higher education				
Private non-profit			√→	√→
Community	√→			

always beneficial; companies should establish which allies they should have a close relationship with (Melander & Pazirandeh, 2019).

4.2.4 | Motivations, drivers, barriers and success factors in open innovation processes for SOI

We found in the analysed studies that firms may have motivations related to sustainability, for instance, when they look for future trends and focus areas within environmental sustainability, to gain awareness of sustainability requirements, to acquire an already existing sustainability technology or to use new sustainability technologies (Arnold, 2017; Behnam et al., 2018; Melander & Pazirandeh, 2019; Wadin et al., 2017).

Companies also collaborate for reasons related to human capital, when they want to transfer knowledge, access to other firms' knowledge, gain specialised knowledge or training, or access to the expertise and competencies of their partners with regard to sustainability issues (Brown et al., 2019; Melander & Pazirandeh, 2019; Mousavi & Bossink, 2020; Pace & Miles, 2020; Reficco et al., 2018). A few examples highlight financial motivations, such as the search for financial benefits, potential revenues or access to financial capital (Bocken et al., 2014; Mousavi & Bossink, 2020; Veleva & Bodkin, 2018).

However, the studies mainly reported organisational reasons to collaborate. For example, the full-text analysis of the selected studies showed that companies decide to involve external actors in sustainability collaboration processes to transform new ideas from an external point of view, obtain and test new ideas and technologies, ensure that the product is in line with customers' needs, legitimise corporate responsibility and improve corporate image, exchange and connect with other actors, expand and reach potential customers in new markets, diversify operations, gain status/recognition or jointly develop resources and capabilities (Aka, 2019; Arnold, 2017; Bocken et al., 2014; Brown et al., 2019; Kanda et al., 2020; Kazadi et al., 2016; Kennedy et al., 2017; Klewitz, 2017; Lee & Kim, 2011; Melander & Pazirandeh, 2019; Mousavi & Bossink, 2020; Neutzling et al., 2018; Reficco et al., 2018; Rossignoli & Lionzo, 2018; Wadin et al., 2017).

In the case of collaborative innovation contests (Greco et al., 2021), the primary motivation of companies is to benefit from the knowledge and creativity of solvers for idea creation and novelty processes, idea validation, networking, and to adapt the business to changes in the environment; while the primary motivations of the solvers are related to learning and increase the knowledge base on sustainability issues (Greco et al., 2021). However, the impact of those innovation contests is not always beneficial, since companies often lack the capabilities to adopt the ideas generated externally or because the employees are reluctant to adopt external ideas. One way to extend the results of the challenge is to link one of the participants with the most promising ideas to support the development and validation of the product, provide space for employees to work on the solution, or outsource the development of the challenge to another partner or company (Greco et al., 2021).

We also identified some internal and external drivers that promote open collaboration processes for SOI. We found internal drivers that include organisational sustainability strategies, internal culture, organisational identity, internal policies and capabilities, organisational structures, employee involvement, internal pressures (cost reduction, resource acquisition and risk prevention), technological leadership, leadership skills, the commitment of top management and integrated management systems (Brown et al., 2019; Jakobsen et al., 2019; Kennedy et al., 2017; Lopes et al., 2017; Neutzling et al., 2018; Reficco et al., 2018; Todeschini et al., 2020; Veleva & Bodkin, 2018; Wadin et al., 2017).

Similarly, we identified external drivers that promote open innovation processes for SOI. Those external drivers include stakeholder pressure, increasing demands for sustainable products, government

TABLE 5 Relationship between partners and coupled mechanisms

Type of partner/ coupled mechanisms	Alliances	Business-non-profit engagement	Co-creation	Cooperation	Coopetition	Collaborative innovation contests	Joint ventures	Cross-sector partnerships	Joint development projects	Innovation networks
Suppliers			√→					√→	√→	√→
Customers			√→					√→	√→	√→
Users			√→	√→		√→	√→		√→	√→
Competitors					√→			√→		
Other firms	√→		√→		√→			√→	√→	√→
Industry associations	√→							√→		
Producers									√→	√→
Professional experts	√→		√→			√→		√→	√→	√→
Agencies									√→	√→
Government			√→					√→	√→	√→
Higher education	√→		√→					√→	√→	√→
Private non-profit		√→	√→	√→	√→		√→	√→	√→	√→
Community			√→	√→	√→		√→	√→		√→

TABLE 6 Relationship between type of partners and SOI orientation

Partner/SOI context	Environmental innovation	Social innovation	TBL
Suppliers	14	0	2
Customers	13	0	4
Users	2	1	3
Competitors	1	0	1
Other firms	15	1	6
Industry associations	5	0	0
Producers	1	0	1
Professional experts	1	1	5
Agencies	1	0	2
Government	6	1	4
Higher education	6	0	3
Private non-profit	6	2	4
Community	3	1	1

TABLE 7 Barriers to collaborate for SOI

Barriers	*N*	Authors
Difficulty finding partners to collaborate	5	Todeschini et al. (2020); Arnold (2017); Behnam et al. (2018); Kazadi et al. (2016); Brown et al. (2019).
Lack of customer awareness and market demand	3	Melander and Pazirandeh (2019); Veleva and Bodkin (2018); Todeschini et al. (2020).
Major cultural differences and conflict stemming from stakeholder diversity	3	Wadin et al. (2017); Kazadi et al. (2016); Brown et al. (2019).
Difficulties with contracts and IP agreements	2	Melander and Pazirandeh (2019); Brown et al. (2019).
Low firms' absorptive capacity	2	Jakobsen et al. (2019); Wadin et al. (2017).
Different expectations regarding the timeframe	2	Mousavi and Bossink (2020); Brown et al. (2019).
Lack of financial resources to start something on their own	2	Kazadi et al. (2016); Todeschini et al. (2020).
Limited access to financing	2	Todeschini et al. (2020); Veleva and Bodkin (2018).
Impossibility to build trust-based relationships	2	Behnam et al. (2018); Brown et al. (2019).
Lack of the necessary knowledge and competencies	2	Rossignoli and Lionzo (2018); Brown et al. (2019).
Lack of alignment of skills, capabilities, and resources to collaborate effectively	2	Brown et al. (2019); Veleva and Bodkin (2018).
Conflicting interests and objectives	2	Stal et al. (2021); Munten et al. (2021).
Authority opportunistic behaviours, and power imbalances	2	Stal et al. (2021); Munten et al. (2021).
Low engagement of value partners, suppliers, and customers	1	Zucchella et al. (2021)
Lack of objectives and a clear horizon	1	Jakobsen et al. (2019)
Low ability to be actively involved in the collaboration process	1	Greco et al. (2021)
Time pressures	1	Greco et al. (2021)
Low alignment of solutions with firm capabilities	1	Greco et al. (2021)
Formal procedures (legal rules)	1	Stal et al. (2021)
No clear motivations and goals to collaborate	1	Brown et al. (2019)
Lack of a common language across sectors/life cycle stages	1	Brown et al. (2019)
Lack of commitment to collaboration	1	Brown et al. (2019)
Lack of certifications, standards, tax regulations across life-cycle stages	1	Brown et al. (2019)
Lack of regulation and incentives	1	Veleva and Bodkin (2018)
Lack of data and indicators to measure and communicate impacts	1	Veleva and Bodkin (2018)
Difficulty accessing and integrating knowledge	1	Brown et al. (2019)
Lack of skilled labour	1	Todeschini et al. (2020)

TABLE 8 Success factors in collaboration processes

Success factors	N	References
Effective communication	6	Lee and Kim (2011); Neutzling et al. (2018); Watson et al. (2020); Melander and Pazirandeh (2019); Neutzling et al. (2018); Juntunen et al. (2019).
Building trust-based relationships	5	Behnam et al. (2018); Melander and Pazirandeh (2019); Todeschini et al. (2020); Lee and Kim (2011); Neutzling et al. (2018).
Building long-term relationships	4	Veleva & Bodkin (Veleva & Bodkin, 2018); Melander and Pazirandeh (2019); Reficco et al. (2018); Neutzling et al. (2018).
Sharing common basic knowledge with the firm's partners	2	Jakobsen et al. (2019); Watson et al. (2020).
Large network of companies or cooperation structure	1	Arnold (Arnold, 2017)
Network catalysts	1	Zucchella et al. (2021)
Culture of experimentation and co-experimentation	1	Zucchella et al. (2021)
Learn from leaders and partners	1	Zucchella et al. (2021)
Ability to identify tensions in the collaboration process	1	Munten et al. (2021)
Advance from firm-centric material development to cross-tier collaboration	1	Siltaloppi and Jahi (2021)
Collaboration between challengers and participants	1	Greco et al. (2021)
Proposing challenges according to participants' backgrounds	1	Greco et al. (2021)
Good relationship with external partners	1	Behnam et al. (2018)
Previous experience of collaboration processes	1	Klewitz (2017)
Ability to attract external actors	1	Behnam et al. (2018)
Coordination and alignment with project teams	1	Lee and Kim (2011)
Sharing resources with external stakeholders	1	Kazadi et al. (2016)
Creative skills and environmental knowledge	1	Bocken et al. (2014)
Creating a strong group identity	1	Watson et al. (2020)
Human 'face-to-face' relationships	1	Reficco et al. (2018)
Employee involvement in open innovation activities	1	Lopes et al. (2017)
Increasing partner knowledge	1	Melander and Pazirandeh (2019)
Sharing risks	1	Melander and Pazirandeh (2019)

subventions, customer awareness of the environmental impact of products, digitalisation as an enabler of environmental innovations, and zero waste laws/policies (Bocken et al., 2014; Kanda et al., 2020; Lee & Kim, 2011; Lopes et al., 2017; Melander & Pazirandeh, 2019; Neutzling et al., 2018; Veleva & Bodkin, 2018).

Finally, we identified some barriers that hinder SOI collaboration and a set of factors that make collaboration processes in an SOI context successful (Tables 7 and 8). For example, Jakobsen et al. (2019) argue that the main barriers in collaboration processes between companies and other allies are related to different dominant logic and power imbalances. The former occurs when firms focus strictly on short-term and quick financial returns, while some allies, such as universities, focus on long-term goals and ways to take advantage of research results. Power imbalances arise when one of the actors considers that it does not need the others' knowledge to achieve the established purpose.

The lack of clear goals is a critical barrier to developing successful open innovation processes (Jakobsen et al., 2019). The lack of capabilities to absorb knowledge is another challenge for a collaborative process. Arnold (2017) found that in a co-creation process, for example, sometimes it is not easy to find suitable participants. Other frequent barriers include lack of commitment in the collaboration process, lack of resources to start something independently, and lack of leadership in the collaboration project or initiative.

Regarding success factors, the study by Melander and Pazirandeh (2019), for instance, suggests that in order for a collaborative process to be successful, collaboration must be based on dialogue and the building of trust between all the actors involved. Similarly, Jakobsen

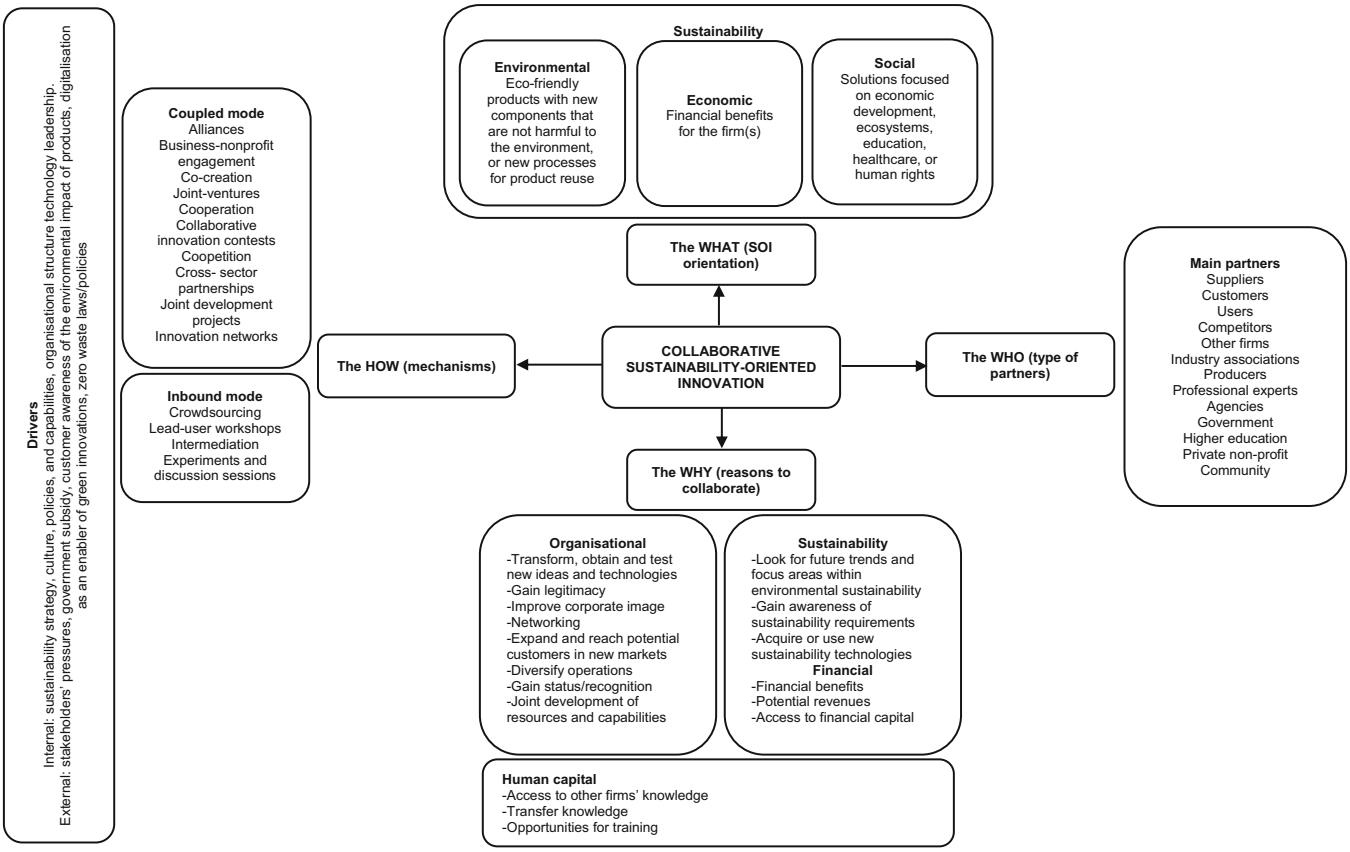

FIGURE 2 Comprehensive conceptual framework.

et al. (2019) point out that previous experience in collaborative processes, sharing common basic knowledge, and the fact that researchers have worked in the industry at some point guarantee a more successful collaboration. In that same regard, Reficco et al. (2018) point out the need to develop human "face-to-face" relationships, while the study by Veleva and Bodkin (2018) on corporate-entrepreneur collaborations for the circular economy highlights the importance of long-term alliances between entrepreneurs and large companies to enable value creation and capture through the establishment of a viable commercial strategy.

5 | CONCLUSIONS

In this systematic literature review we analysed the *what*, *how*, *who and why* of open innovation processes in guiding businesses in their innovation efforts towards sustainability. Based on the results of our content analysis, we produced a comprehensive conceptual framework that synthesises the main findings of this study (Figure 2).

Based on the analysis of the selected scientific articles, we encourage researchers to adopt a temporal and relational perspective to study open innovation for SOI, in order to determine which partners are most important to the firm and at what stage of the innovation process they should be integrated, as suggested by Aka (2019). Further work is requiered to analyse the level of integration of partners and their impact on the sustainability performance of the firms.

There is abundant room for further work in examining how motivations, drivers, barriers, and success factors in open innovation for SOI vary according to contingency factors and the characteristics of the firms. Another area for more extensive research is the difference between the barriers that prevent the establishment of collaboration processes for SOI and the barriers that appear when the collaboration process is happening.

The results of our study could be a source of information to guide the formulation and evaluation of public policies related to technological change and sustainable development. This study could also help to determine and address the fundamental elements, drivers, barriers, and incentives of the sustainability-innovation process. The study also provides essential elements for managers of different business sectors since it identifies and synthesises the main mechanisms to establish collaborative processes that contribute to the sustainability of the planet. We also present an overview of the main factors for successful collaborative processes, helping to reduce the likelihood of failure in collaborations between companies and other actors.

We found, for instance, that digital technologies are critical drivers of collaborations for sustainability purposes as they are a means to provide new types of products and services with societal benefits. Hence, companies now need to review their inter-firm collaboration and coordination methods to meet the expectations of

strategic or potential customers. In the context of environmental innovation, for example, there is a much greater need to establish governance structures and mechanisms capable of reconciling the points of divergence between partners (He et al., 2020).

Another critical point derived from our review is the call for a systemic perspective towards sustainability, given that lacking a systemic view in open innovation processes for SOI can only lead to incremental improvements, which are not adequate to promote real impacts at a system or societal level. Moreover, even those same efforts can hinder a broader system transition since they can stimulate a linear model of production and consumption (Siltaloppi & Jahi, 2021). In that vein, it is necessary to move from a company-centric perspective to cross-tier collaborations, as suggested by Siltaloppi and Jahi (2021). For example, in the context of collaborative innovation for the circular economy, it is important to align technological developments with transformations in business models and the search for changes in regulations and social expectations (Siltaloppi & Jahi, 2021).

Zucchella et al. (2021) also call for a multi-level view of firms' sustainability transition, including entrepreneurial, organisational, and network levels. However, Zucchella et al. (2021) argue that a critical barrier in this process is that established companies tend to think more in terms of supply chains rather than networks or innovation ecosystems, which would allow established firms to partner with different actors, such as innovative start-ups. In that context, a culture of openness and collaboration is crucial driver for the transition towards more circular business models.

We consider that the results of this review contribute to the debate on incremental improvements and systemic transformations, highlighted in previous scientific literature and public guidelines. This review has focused mainly on the role of the private sector in developing innovative solutions and new technologies to meet the most critical challenges facing our planet. However, in line with Ritala (2019), we advocate for a more critical view of sustainable innovation, since many times companies 'tend to incrementally offset negative environmental and societal impacts, rather than eliminate them' (Ritala, 2019, p. 22).

The transition towards new sustainable business models is more difficult for large companies as they face various obstacles in interconnecting the economic, social, and ecological spheres (Ritala, 2019). In that sense, new opportunities for start-ups are emerging in the context of sustainable consumption, for example, through circular business practices (United Nations Environment Programme, 2019), since new ventures can quickly implement radical solutions. Unlike established firms, start-ups from birth can have a high degree of orientation towards developing innovative solutions to solve and mobilise society towards change. However, this cannot be achieved by individual start-ups; they need to be integrated into an ecosystem to benefit from the support and knowledge of other actors while also becoming agents of change within the same innovation ecosystem.

In summary, more integrated and system-based approaches are needed to 'enable cross-linkages to be explored and system-wide effects to be managed, so that policies can effectively support a number of social, economic and environmental goals to support human well-being, ensuring that various preconditions for this well-being are in place' (United Nations Environment Programme, 2019, p. 5). Furthermore, an SOI system perspective is also beneficial to understand that social, environmental, and economic spheres are interconnected; changes in one of those systems affect the other systems, resulting in a coevolutionary development (Ritala, 2019).

For instance, 'environmental issues are closely related to social issues such as hunger, consumption patterns, health, education, inequality, gender gaps, waste and sanitation, refugees, migration, conflicts and intolerance' (United Nations Environment Programme, 2019, p. 9). Incremental improvements are important but not enough since it is challenging to determine if they will have long-term positive and negative impacts. In fact, digital technologies have often created unintended consequences, and for that reason, they can be both a positive or negative driver of environmental change (United Nations Environment Programme, 2019).

We are aware that this study has some limitations. For example, much of our sample of articles is composed of qualitative studies, which reduces the amount of scientific literature covered. However, such a qualitative approach is essential to provide a complete picture to describe how companies are developing open innovation processes for SOI. In addition, the use of only one database and the restrictions in the document types included can also be an important limitation of this study. For instance, we did not search for grey literature, which can help address the problems of time lag (Adams et al., 2016).

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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APPENDIX A: CODEBOOK FOR SYSTEMATIC LITERATURE REVIEW (DESCRIPTIVE ANALYSIS)

Main categories	Description/examples
Study objective	The main purpose of the study.
Methodological approach	Whether the study is qualitative, quantitative or mixed.
Research design	Whether the study is a single case study, multiple case study, survey-based, etc.
Data collection technique(s)	The techniques used to collect information: in-depth interviews, observation, focus groups, structured questionnaires, secondary databases, etc.
Source of information	Anything that might inform or provide knowledge for data collection.
Level of analysis	Intra-organisational Organisational Extra-organisational Inter-organisational Industry, regional innovation systems, and society
Research object	Individuals, groups/teams, projects, functional areas, business units. Firms, other (non-firm) organisations, strategies, business models. External stakeholders, individuals, communities, organisations. Alliances, networks, ecosystem. Industry development, inter-industry differences, local regions, nations, supra-national institutions, citizens, public policies (Chesbrough & Bogers, 2013) (Bogers et al., 2017)
Sample	Number of observations taken for analysis.
Business sector	Type of business sector of the focal firm(s) (if applicable).
Theoretical lens	Theories or frameworks adopted to explain the phenomenon.
Country	Country in which the study was conducted.

APPENDIX B: CODEBOOK FOR SYSTEMATIC LITERATURE REVIEW (CONTENT ANALYSIS)

Main categories	Subcategories	Description/examples	Source(s)
Sustainability orientation (*the what*)	Triple bottom Line	This is the dimension where the foundations are environmental, social and economic goals.	(Saunila et al., 2018; Veleva & Bodkin, 2018)
	Social	The social dimension is about paying attention to human capital development, job creation and safety issues, among others	Saunila et al. (2018)
	Environmental	The environmental dimension encompasses factors such as land use, waste handling, hygiene, and energy and water consumption (Saunila et al., 2018).	
Collaboration partners (*the who*)	Business enterprises	Suppliers, specialised knowledge services providers and commercial research institutes, customers, competitors or other businesses	OECD/Eurostat (2018)
	Government	Government research institutes, ministries, and agencies	
	Higher education	Universities	
	Private non-profit	Private non-profit research institutes and other private non-profit organisations	
Collaboration mechanisms (*the how*)	Inbound	IP in-licencing Contracting with external R&D service providers Customer relations networks Value-chain networks University research grants Information networking (conferences, conventions) Publicly funded R&D consortia Idea and start-up competitions Crowdsourcing Supplier innovation awards Use of innovation intermediaries Earlier supplier integration Customer co-development External knowledge sourcing and integration	(Chesbrough & Brunswicker, 2014; Enkel et al., 2009; Mazzola et al., 2012; Öberg & Alexander, 2019)
	Outbound	Contracting-out Corporate business incubation Customer relationships Outsourcing alliances Selling of market-ready products IP out-licencing and patent selling Spinoffs Venturing Bringing ideas to market R&D resources made available to third parties Commercialisation of external technologies	
	Coupled	Co-patenting R&D alliances Joint ventures Joint research teams Partnerships Collaborative innovation Industrial districts Industrial relationships Networks Consortia Clusters Communities	

(Continues)

Main categories	Subcategories	Description/examples	Source(s)
Motivations/ reasons to collaborate (*the why*)	Sustainability	Contributing to sustainability goals, to environmental, social or economic, challenges or to community sustainability	(Gray & Stites, 2012; Ordonez-ponce et al., 2020)
	Human capital	Gaining knowledge/learning, gaining expertise, sharing own experiences, improving competencies	
	Organisational	Improving organisations' sustainability, innovation capacity, building new relationships, improving reputation, gaining legitimacy, becoming more influential, gaining access to new markets, marketing opportunities, networking, collaborating with others, engaging with the community, improving relationships.	
	Financial	Improving financial performance, reducing costs, funding opportunities, developing new products/services, creating new businesses, attracting new investors, increasing financial resources	
	Physical	Increasing physical resources, improving processes	
Drivers	Internal	Size, availability of financial resources, organisational complexity, sustainability, innovation management; physical and knowledge capital stock	(Gray & Stites, 2012; Pellegrini et al., 2019)
	External	Social perceptions, expectations and preferences; technological developments; concerns about globalisation; environmental regulations; decline in government efficacy; innovation-oriented industrial relations; market pressures	
Barriers to collaborate	Open codification	Factors that hinder the development of collaborative processes for SOI.	
Success factors	Open codification	The main factors that influence the success of open innovation processes for SOI.	

Publication III

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RESEARCH ARTICLE

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Business digitalisation as a driver of environmental and economic sustainability in micro, small, and medium-sized enterprises

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Abstract

In this study, we examine the direct relationship between business digitalisation and improvements in economic sustainability, as well as the potential mediating role of environmental sustainability. We also examine the potential role of company size as a moderating variable in these relationships. We gathered data from micro, small and medium-sized enterprises (MSMEs) in Finland. Contrary to initial expectations, our findings reveal that there is no direct and significant relationship between business digitalisation and the economic sustainability of enterprises; this relationship is only possible through the mediating role of environmental sustainability. We also found that, although high levels of environmental sustainability may result in improved economic outcomes, the strength of this relationship is much weaker for microenterprises than for their larger counterparts. Altogether, these results underscore the complex interplay between digitalisation and sustainability outcomes within the context of small businesses.

KEYWORDS
business digitalisation, digital technologies, environmental sustainability, microenterprises, MSMEs, sustainable business

1 | INTRODUCTION

Digitalisation has drastically revolutionised how individuals, societies, institutions, and companies operate and interact (Brenner & Hartl, 2021). In the business context, digitalisation involves incorporating digital products, services, and processes within companies (Hull et al., 2007; Proksch et al., 2021) to transform internal procedures and reach new markets (Gaglio et al., 2022). Consequently, business managers of companies from different sectors and sizes are increasingly interested in understanding the impact of the digital revolution on their organisations, particularly in transitioning from an industrial to a digital-centric economy (Björkdahl, 2020).

For micro, small, and medium-sized enterprises (MSMEs), digitalisation is a critical factor that may significantly support companies in their pursuit of enhanced economic profitability. For instance, the use of IT-related resources, such as computerised accounts or websites, has been proven beneficial for microenterprises in terms of improving internal operational efficiency, increasing operational capabilities, and enhancing external communications (Gherhes et al., 2016), which, in turn, are associated with superior economic benefits (Gherhes et al., 2016).

Since MSMEs are typically established with limited resources (Simba & Thai, 2019), the economic effect of business digitalisation is critical for achieving so-called economic sustainability. In this context,

economic sustainability refers to a business's capacity to operate in an economic balance that is not based on debts (Nasiri, Saunila, Rantala, et al., 2022). However, as Brenner and Hartl (2021) claimed, MSMEs must not focus solely on economic value creation; it is essential to also integrate environmental considerations into their strategic frameworks (Cantele & Zardini, 2018; Yang et al., 2024). Indeed, the global agenda concerning climate and environmental preservation places growing emphasis on the environmental sustainability of the smallest businesses (Karaeva et al., 2023). Thus, in addition to the challenge of digitalisation, MSMEs are transitioning towards environmental sustainability.

The emphasis on MSMEs is based on the argument that these businesses are a vital segment of the economies of developing, emerging, and even more developed countries (Simba & Thai, 2019). MSMEs comprise approximately 90% of all companies, generate between 60% and 70% of employment, and contribute to 50% of global Gross Domestic Product (GDP) (United Nations, 2023). In Europe, approximately 24.3 million MSMEs were active in Europe by 2022 (in the EU-27), accounting for 99.8% of all the enterprises (Di Bella et al., 2023).

Although MSMEs substantially contribute to global business activities, total productivity, and GDP at an aggregate level, they also significantly contribute to the production of solid waste and contamination of water and air resources, which in turn have an adverse effect on the natural environment (Rehman et al., 2022; Roxas, 2021). For instance, MSMEs account for a substantial portion of both environmental pollution and greenhouse gas (GHG) emissions, with 50% of GHG emissions and 30%–60% of energy use in the business sector (OECD, 2022).

Considering the cumulative environmental impact of MSMEs, these companies play a critical role in addressing the climate emergency and other planetary issues, which are becoming increasingly challenging to contain daily, such as the depletion of natural resources and loss of biodiversity (OECD, 2023b). The transition towards environmental sustainability is not possible if MSMEs are left behind. For that reason, small businesses are called to contribute to planetary challenges by adopting greener practices in their operations (e.g., minimising their environmental footprint) or by introducing ecological innovations (OECD, 2023b).

In the context of the twin green and digital transitions (Di Bella et al., 2023), it is unquestionable that the pursuit of both business digitalisation and environmental sustainability represents a crucial avenue for businesses to grow in the modern economy (Denicolai et al., 2021). However, despite the widely recognised role of MSMEs in digital and environmental transitions, along with the tremendous benefits of digitalisation in driving both environmental and economic sustainability in MSMEs, there has been little agreement in the scientific literature to date on whether and how business digitalisation can support the environmental and economic goals of these enterprises (Broccardo et al., 2023; Denicolai et al., 2021).

Based on the above, we analyse the relationship between these constructs in the context of MSMEs in Finland. This geographical setting is particularly interesting because Finland can be considered an MSME country, making it an ideal context for this study. For instance, in 2021, MSMEs accounted for 99.9% of all Finnish companies (Statistics Finland, 2023). The majority of companies employing fewer than 10 persons represent 96.6% of all active businesses in Finland, while small and medium-sized enterprises (SMEs) account for 2.8% and 0.5%, respectively. Conversely, large companies account for 0.1% of the total active companies (Statistics Finland, 2023).

Although Nordic countries are well positioned to capitalise on the benefits of digitalisation due to their robust access to digital infrastructure, they exhibit some differences in the stages of digitalisation implementation (Berlina & Randall, 2019). We considered Finland an interesting context of study, particularly because it leads the digital transformation arena in Europe. According to the Digital Economy and Society Index (DESI) (European Commission, 2022) Finland ranks first among EU countries on the integration of digital technology, with scores significantly higher than the EU average. Digital technologies are at the heart of Finnish business functions, with 82% of Finnish SMEs having at least a basic level of digital intensity (European Commission, 2022), significantly higher than the EU average of 55%.

Finnish companies also surpass the EU average in both cloud solution adoption and integration of AI technology in business operations, with 66% using cloud solutions and 16% incorporating AI. Additionally, 77% of the companies in Finland employ Information and Communications Technology (ICT) at medium- to high-intensity levels for environmental action (European Commission, 2022). Regarding Finnish microenterprises, in 2020, 96% of the businesses employing at least 10 individuals had websites, with 75% utilising cloud services (Statista, 2021).

Additionally, Finland is one of the countries with the most significant progress in terms of implementing strategies for a circular economy and environmental protection, and is committed to becoming carbon neutral by 2035. Finland has also developed the world's first national roadmap to a circular economy and has been at the forefront of adopting EU environmental policies (OECD, 2021a). Therefore, many companies have made enormous sustainability commitments that allow them to gain a first-mover advantage (OECD, 2021a).

Digitalisation and a dual focus on environmental and economic sustainability are relevant factors in the business arena. However, the academic literature has seldom discussed the potential mediating role of environmental sustainability in the relationship between business digitalisation and economic sustainability, particularly within the context of MSMEs. In line with the aforementioned, we pose the following guiding research question: What is the relationship between business digitalisation, environmental sustainability, and economic sustainability, and how does this relationship differ for microenterprises compared to their larger counterparts?

The relevance of our study lies in the fact that the existing evidence regarding the proposed relationships remains inconclusive. For instance, some studies assert that digitalisation directly improves a company's economic outcomes (Bellakhal & Mouelhi, 2023; Martínez-Caro et al., 2020; Truant et al., 2021), while others find no direct relationship between the use of digital technology and a firm's financial performance (Tsou & Chen, 2021). Furthermore, research indicates

that digitalisation can act as a catalyst for environmental sustainability (Haq & Huo, 2023; Issah et al., 2024).

Within the broader Nordic context, particularly in Finland, only a limited number of studies have explored the relationship between digitalisation and enterprises' environmental and economic sustainability. For instance, Saunila et al. (2019) examined the relationship between smart technologies and corporate sustainability in 280 Finnish SMEs with 20–250 employees. The primary objective of this study was to examine the relationship between the adoption of smart technologies and various dimensions of sustainability within these companies. However, no direct association between smart technologies and environmental sustainability was found.

Similarly, Sipola et al. (2023) qualitatively examined the role of artificial intelligence in advancing sustainability in large Finnish enterprises. The authors argued that the pursuit of environmental sustainability has become a pivotal objective among Finnish enterprises, increasingly influencing their competitive advantages. Furthermore, they highlighted the significant potential of AI applications in enhancing environmental sustainability within firms.

In light of existing research, this study makes two main contributions. First, it examines whether and how business digitalisation is directly associated with improvements in companies' environmental and economic sustainability, and whether environmental sustainability plays a mediating role in this relationship. Second, this study considers the potential moderating role of company size in determining whether microenterprises exhibit different patterns in the hypothesised relationships.

The remainder of this paper is organised as follows. Section 2 examines the related literature and research hypotheses. Section 3 outlines the methodological aspects of this study. Section 4 presents the main results of the research, while Section 5 discusses the main implications of the results, contextualising them within the framework of the proposed hypotheses and existing research. Section 6 concludes the paper with a reflection on the study's overall contributions, future lines of enquiry, and potential limitations.

2 | THEORETICAL BACKGROUND

Although digitalisation is a phenomenon of enormous relevance to ensure the resilience and growth of companies of all sizes, its adoption is imperative for MSMEs. Business digitalisation has the potential to provide multiple benefits to MSMEs, which often operate in a context of limited resources and business knowledge (Cunningham et al., 2023). MSMEs are known for their adaptability. In that sense, digitalisation provides MSMEs with the basis for seeking disruptive innovation, improving their products, services, and business processes, and increasing business performance, including economic benefits (Cunningham et al., 2023).

According to the resource-based view (RBV), companies differ in terms of their resources and competencies (Barney, 1991; Del Giudice et al., 2017). Based on this theoretical framework, integrating new digital technologies is regarded as a means of selecting resources and enhancing capabilities to create a sustained competitive advantage (Nafizah et al., 2023). We relied on the postulates of this theory to explain the complex relationships among business digitalisation, environmental sustainability, and economic sustainability.

Given that the RBV focuses on how a firm's unique resources and capabilities can lead to competitive advantage and superior business performance (Barney, 1991), we found this theory appropriate to guide the assumption that companies can effectively develop and use their digital capabilities in their environmental and economic efforts. However, as outlined by Hassan et al. (2023), it is important to note that there is an extensive debate in management research about whether to consider digital capabilities as a unique and inimitable resource or as a more generic resource.

Although digital technologies are widely available to businesses across all sectors, making them easily adaptable by competitors, companies with unique experiences can provide their customers with digitalised products, services, and processes that are difficult to imitate, thereby achieving a sustained competitive advantage. Based on this, we consider the RBV helpful in explaining how a company's internal resources (e.g., digital capabilities) and characteristics (e.g., size) interact with its environmental and economic outcomes.

2.1 | Business digitalisation and economic sustainability

Business digitalisation entails the integration of digital products, services, and processes within a company (Hull et al., 2007; Proksch et al., 2021). Digital products and services may include a wide array of digital elements, media utilisation or applications, and essential digital components that deliver their primary functionality (Proksch et al., 2021). Conversely, digital processes encompass all actions that generate value through digital technologies, offering frameworks to develop architectures aimed at providing complementary solutions (Proksch et al., 2021).

Business digitalisation is beneficial for developing a digital mindset, simplifying the process for companies to understand and address their consumers' needs, thereby avoiding resource wastage, financial losses, and conflicts with clients (Wang et al., 2023). It also enables owners of small enterprises to enhance their business processes, leading to innovative offerings, better adaptation to changing consumer trends, and the introduction of new products and services (Hassan et al., 2023). To determine whether digitalisation is financially rewarding, some studies have found that companies with a high level of digitalisation are more likely to adopt advanced digital technologies to add value to their portfolio of products and services and create digital value for their customers, which in turn can lead to superior economic performance (Wang et al., 2023).

However, evidence concerning the link between digitalisation and business economic outcomes remains unclear. In practice, this relationship proves to be much more complex. For instance, some studies claim that increased digitalisation is not necessarily associated with improved economic benefits. In fact, at times, digitalisation can even

introduce new economic challenges for companies (Yu et al., 2023). Other authors also indicate that business digitalisation can negatively impact a company's overall outcomes (Wang et al., 2023). For instance, Yu et al. (2023) argued that digitalisation can lead to a paradoxical scenario in which businesses must address rapid digital transformation, potentially resulting in unintentional competition that could reduce business revenue or even result in negative returns.

Although there is still not enough consensus regarding the economic benefits of business digitalisation, we align with the body of literature claiming that digital technologies can foster operational efficiency, reduce production costs, and increase business profits through improved information processing (Li et al., 2020). This is mainly because, from the theoretical perspective adopted in this study, business digitalisation is a key resource that can contribute to long-term financial stability and growth. To maintain consistency with this statement, we posit the following hypothesis:

H1. Business digitalisation is positively related to firms' economic sustainability.

2.2 | Business digitalisation and environmental sustainability

The transformation and exploitation of the Earth's resources into wealth through intensive industrial activities have adversely affected natural ecosystems and societies (Caglar et al., 2023; Linnenluecke & Griffiths, 2013). Thus, while the economic activities of many companies are the primary source of emissions, pollution, and biodiversity loss, these same companies are suffering the devastating consequences of climate change and other planetary concerns (Saget et al., 2022).

In the context of the growing urgency to safeguard the Earth from irreversible ecological harm, companies are expected to increase their concerns about the natural environment and reduce the environmental impacts of their operations (Lucato et al., 2017). According to Lee and Roh (2023), digitalisation is a critical driver in enhancing business efficiency and reducing carbon emissions because it allows companies to advance in terms of resource utilisation and allocation, leading to environmental improvements.

Although digitalisation is expected to assist companies in their strategic efforts to enhance their environmental sustainability, not all studies have demonstrated the beneficial impact of business digitalisation initiatives on environmental sustainability (Bendig et al., 2023). For instance, Li et al. (2020) argued that digital technologies can increase the competitive dynamics of the business environment, potentially influencing the achievement of companies' environmental strategies.

However, a larger body of literature argues that, in addition to optimising resource allocation, digitalisation allows companies to enhance the visibility and communication of their environmental practices (Yang et al., 2023) to a range of stakeholders. This can be attributed to companies' concerns about preserving their reputation, particularly among clients, while minimising their environmental impact (Yang et al., 2024). From a knowledge management perspective, digitalisation also supports companies in reducing the costs associated with external knowledge search (Yang et al., 2023), as it enables companies to access critical and strategic information through both sharing and resource agglomeration effects (Wu et al., 2023).

Access to external knowledge would further contribute to better absorption of environmental sustainability-related knowledge in the form of specialised training, valuable case studies, or industry-specific sustainability reports. Additionally, when small businesses acquire new knowledge and competencies, they are more likely to establish relationships with other organisations and generate new products and processes aligned with improvements in environmental performance (Ardito et al., 2021). Other authors also suggest that digitalisation is positively associated with a greater probability of engaging in environmental innovation (Guo et al., 2023).

Thereby, we hypothesise that:

H2. Business digitalisation is positively related to firms' environmental sustainability.

2.3 | Environmental sustainability and economic sustainability

Companies' environmental sustainability is expected to improve due to the strategic opportunities associated with the environmental responsibility demanded by different stakeholders (de Villiers et al., 2011). Raza and Woxenius (2023) asserted that an increasing body of research suggests a positive association between sustainable business practices and economic sustainability. The rationale behind this positive relationship is that companies that prioritise environmental sustainability and incorporate environmentally responsible practices are more likely to experience improvements in their economic outcomes (Raza & Woxenius, 2023).

For example, de Villiers et al. (2011) argued that strong environmental sustainability is generally associated with reduced operating costs and greater economic gains due to the exploitation of market opportunities derived from the demand for environmentally sustainable goods and services (de Villiers et al., 2011). According to Raza and Woxenius (2023), the presumed positive relationship between the two constructs can be mainly attributed to the reputational benefits associated with being an environmentally responsible company, the cost savings and operational efficiencies derived from environmentally responsible practices, and the evolving regulations and societal expectations that incentivise companies to constantly improve their environmental practices.

The relationship between environmental and economic sustainability has been examined at the corporate level from various disciplines and perspectives. Although the findings are mixed, an extensive body of literature provides significant evidence supporting a positive association (Busch et al., 2023). However, most studies analysing the relationship between environmental sustainability and economic

performance have predominantly focused on large companies, exposing the need for more studies to determine whether the advantages of adopting environmentally sustainable practices are limited to large corporations (Cantele & Zardini, 2018).

Traditionally, the literature on the economic benefits of environmental sustainability has been dominated by analyses of the causal relationship between environmental and financial performance, assuming that it leads to a win-win situation. From the RBV, the logic of this relationship is that environmental practices are valuable resources capable of increasing economic results through cost reduction, product and process improvements, and favourable positioning of the business image, leading to higher sales and profitability (Rintala et al., 2022). Accordingly, it is expected that firms can improve their economic position based on the premise that environmental practices, such as reducing pollution and energy consumption and using fewer resources, will increase firm profitability (Amankwah-Amoah & Syllias, 2020).

Accordingly, we hypothesise that:

> **H3.** Environmental sustainability is positively related to firms' economic sustainability.

2.4 | The mediating role of environmental sustainability between business digitalisation and economic sustainability

The question regarding to what extent an increase in business digitalisation can lead to better environmental and economic sustainability is attracting the attention of both scholars and managers. As explained by Wang et al. (2023), this is a critical concern for companies, as most of them are still in the exploratory stage of digital adoption, and achieving a mutually beneficial balance between economic and environmental sustainability in the context of digitalisation can be challenging.

Previous studies have suggested that firms can enhance their environmental and economic sustainability through investments in digital technologies (Wang et al., 2023). However, the relationship between digitalisation, environmental sustainability, and economic output was not necessarily positive in all cases. For instance, even if companies can improve their environmental practices with the support of digital tools, the influence of environmental improvements on economic sustainability can still vary (Li et al., 2023).

Companies may also take advantage of the economic advantages and market opportunities derived from improving the environmental performance of their products, services, and processes through digitalisation. Thus, digitalisation is expected to affect different business sustainability targets, directly enhancing economic sustainability or through environmental practices, ultimately resulting in positive economic performance (Broccardo et al., 2023).

Although it has been proven that digitalisation can significantly impact economic outputs, the question remains whether environmentally sustainable practices driven by digitalisation can lead to better economic sustainability for firms (Broccardo et al., 2023). In this context, environmental sustainability can play a mediating role by allowing companies to realise the full potential of business digitalisation for their economic sustainability. Based on existing research, we propose the following hypothesis to test the presence of this association:

> **H4.** Environmental sustainability positively mediates the relationship between business digitalisation and economic sustainability.

2.5 | The moderating role of firm size

Differences in organisational structures and strategies between large companies and MSMEs, there is heterogeneity between microenterprises and SMEs (Rastrollo-Horrillo, 2021). Gherhes et al. (2016) and Rastrollo-Horrillo (2021) highlighted two distinctive characteristics of SMEs. (1) Smallness: these enterprises face more resource constraints, such as a lack of capital asset technologies, and face multiple challenges in gaining access to financial and human resources. (2) Owner centrism: Microenterprises are companies with few permanent employees; therefore, strategic decisions are the responsibility of the owner or manager, who directly influences the management style and performance of the business.

Due to their small size, microenterprises are expected to demonstrate distinctive attitudes and strategic reactions to digitalisation (Jones et al., 2014) compared to SMEs. In regards to digitalisation, the well-known constraints associated with small businesses (e.g., financial, skilled personnel, and resistance to change) may be more pronounced in microenterprises (Radicic & Petković, 2023), implying that many businesses are struggling to adapt to the digital imperative and lag behind in the digital transition (OECD, 2023b). Business digitalisation also can have heterogenous or modest effects in smaller firms (Radicic & Petković, 2023).

Furthermore, scientific evidence suggests that company size is a critical factor influencing perceptions of the economic rationale for sustainable practices (Revell & Blackburn, 2007; Roxas, 2021), with microenterprises often demonstrating the weakest awareness of commercial arguments in favour of environmental sustainability (Jibril et al., 2024; OECD, 2023b).

In the Italian context, Broccardo et al. (2023) found that company size strongly influences digital implementation and sustainability, demonstrating that larger companies tend to exhibit higher levels of digitalisation and sustainability performance, which in turn can be associated with better profitability. In the case of microenterprises, managing digital, environmental, and economic aspects can be complex and challenging. Since microenterprises often lack the necessary financial strength, it is challenging to fully embrace digitalisation, which typically involves modifying products, processes, and organisational structures (Pronti et al., 2024).

Additionally, the high dependence and significant influence of the owner or manager on the strategic decisions of microenterprises, such as those related to translating pro-environmental ideals into practical

actions, can improve the environmental sustainability of the firm if the manager has a positive attitude towards green business. However, this is not always the case (Pronti et al., 2024). We concur with Ardito et al. (2021), who claimed that context matters, and that small firms differ in their approaches to strategy execution and, notably, in their capacity to allocate resources towards digitalisation and environmental and economic sustainability. Accordingly, we propose that:

H5a. Firm size moderates the relationship between business digitalisation and economic sustainability.

H5b. Firm size moderates the relationship between business digitalisation and environmental sustainability.

H5c. Firm size moderates the relationship between environmental and economic sustainability (see Figure 1).

3 | METHODS

3.1 | Sample and data collection

This study's empirical context is based on a sample of 95 micro, small, and medium-sized enterprises (MSMEs) in Finland's Päijät-Häme region. Located in Southern Finland, the Päijät-Häme region has a population of approximately 206,000 (The Regional Council of Päijät-Häme, 2024). The region has forests and water as its primary resources. Significant economic sectors include forestry, furniture manufacturing, and the metal, plastic, and textile industries (Vanhamäki et al., 2020). Notably, Päijät-Häme was among the first regions in Finland to implement a circular economy roadmap (Vanhamäki et al., 2020), with sustainable business from the bio-circular economy, new consumption models, innovative circular solutions, and sustainable transport and energy solutions as the main guiding themes.

In this study, the unit of analysis was a company, while the unit of observation was the manager or owner of a company. We chose managers and owners as respondents to assess our constructs because they are expected to have adequate knowledge about their companies' operations, their orientation towards digitalisation, and the environmental and economic sustainability achieved by the companies they lead (Saunila et al., 2019).

The data for this study were collected via a web-based survey, encompassing both firm- and study-theme-related constructs. Respondents were identified from the database of a local supporting business organisation, selected because it is the most comprehensive list available (to the best of the researcher's knowledge). It covered a large number of small, active companies that were difficult to find because most of the databases covered larger companies. The initial sample comprised approximately 3000 firms with a maximum of 250 employees, adhering to the threshold identified by the Federation of Finnish Enterprises in the Päijät-Häme region. This sample yielded

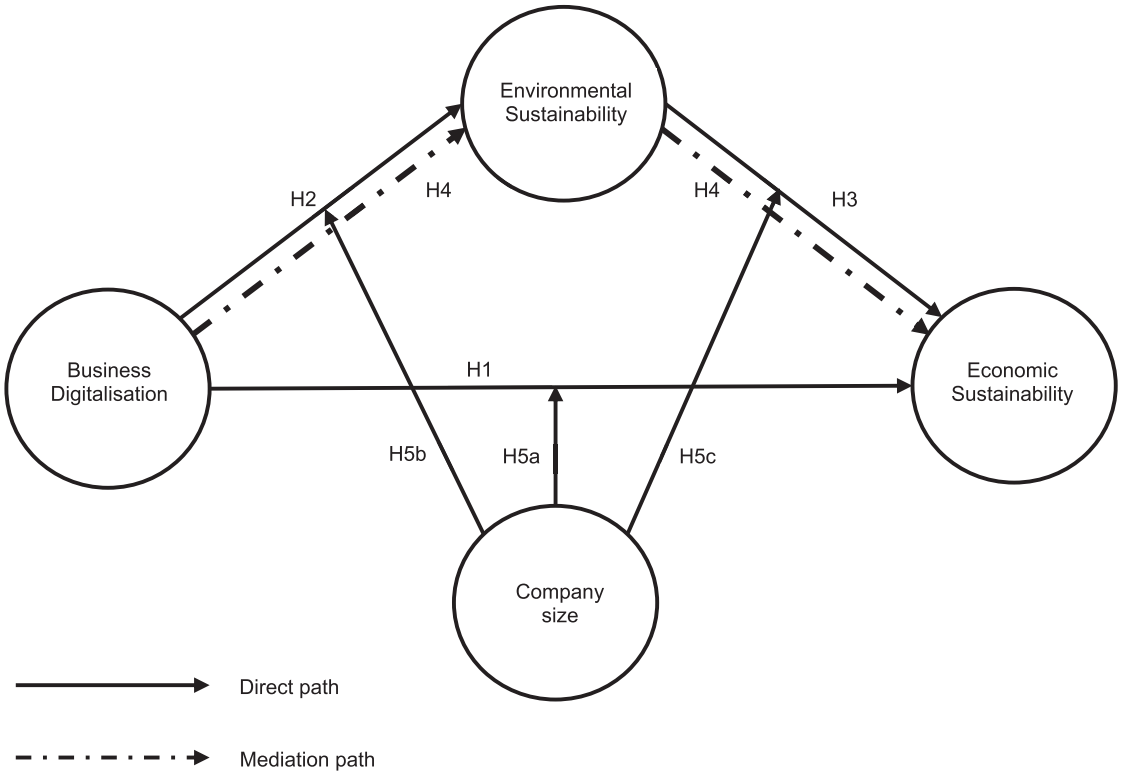

FIGURE 1 Proposed research model. *Source:* Authors' own elaboration.

98 valid responses. Following data screening, three questionnaires were excluded from the analysis to avoid bias in the sample composition, given that the respondents claimed to lead a company with more than 249 employees.

Table 1 presents the companies' main characteristics. It is important to note that most of them were microenterprises (62%). These microenterprises had an average of three employees, with 42.4% having only one employee, in addition to the manager/owner. Additionally, 39% of all the companies were well-established organisations (more than 20 years old), while the second largest group comprised companies with a maximum of 5 years since being founded (32%).

3.2 | Measures

3.2.1 | Dependent variable

Economic sustainability was measured based on two items (Table 2) scored on a 4-point Likert scale ranging from 1 (weak) to 4 (excellent). In this study, we considered economic sustainability as a firm's outcome, indicating profitability and economic sustainability improvements. Profitability, a key organisational performance criterion, has been used previously in studies addressing the effects of Industry 4.0, on firms' economic gains (Calış Duman & Akdemir, 2021), as well as in the digital-sustainability-economic performance nexus in Italian companies (Broccardo et al., 2023). On the other hand, economic sustainability is an indicator used to determine whether companies operate in an economic balance that is not based on debts (Nasiri, Saunila, Rantala, et al., 2022).

TABLE 1 Sample description.

Characteristics	Frequency (*n*)	Percentage (%)
Industry type		
Production	26	27
Services	69	73
Age (years)		
5 or fewer	30	32
6–10	12	13
11–15	11	12
16–20	5	5
More than 20	37	39
Customer base		
B2C	26	27
B2B	69	73
Number of employees		
0–9 (Micro)	59	62
10–49 (Small)	23	24
50–249 (Medium)	13	14
Total	95	100

Source: Authors' own elaboration.

3.2.2 | Independent variable

Business digitalisation is measured with five items (Table 2) and scored on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items were adapted from previous studies such as Lee and Roh (2023) and Proksch et al. (2021). In this study, we defined business digitalisation as the growing integration of digital products and services and digitalised processes (Hull et al., 2007; Proksch et al., 2021). In the context of this study, high digitalisation scores suggest that companies offer digital-related products or services and use digital processes to support their offerings (Proksch et al., 2021).

3.2.3 | Mediating variable

To measure companies' overall environmental sustainability, we used a single item (Table 2) in which the participants were asked to evaluate their companies' environmental sustainability (minimising environmental impact) using a scale ranging from 1 (weak) to 4 (excellent). In this study, environmental sustainability was defined as the level at which an organisation's strategy contributes to minimising its impact on the natural environment (Nguyen & Adomako, 2022).

Although the use of single-item measures may introduce some limitations compared to multiple-item measures, they can be adopted when the empirical study refers to a particular object or phenomenon, and if the measure and object of the study are made clear to the respondents (Saunila et al., 2019). For instance, Manika et al. (2015) conducted a study in seven different organisations in the United Kingdom where they used a single-item measure to evaluate the perceived environmental behaviour of the organisations. They asked a sample of 1204 employees to indicate how environmentally friendly the organisation they were working for was in comparison to what it could be.

A similar single-item measure was used to evaluate the sustainability strategy (Saunila et al., 2019; Ukko et al., 2019) and environmental sustainability (Nasiri, Saunila, Rantala, et al., 2022) of SMEs in Finland. Additionally, Prömpeler et al. (2023) explored the director's and CEO's environmental sustainability focus in the Dutch housing sector using survey data and employing a single-item measure. According to these authors, single-item measures may have the same predictive validity as multiple-item measures, as they avoid irritation among respondents by requiring them to respond to numerous similar questions (Prömpeler et al., 2023).

We used varying scale ranges to measure the constructs. This strategy aims to minimise common method bias (CMB), as recommended by Podsakoff et al. (2012). They suggested that applying similar question formats could lead respondents to use the same thought processes for different questions, potentially biasing their results. By varying the response formats, we reduced the likelihood that answers to one question would influence the responses to others. Memon et al. (2023) also suggested that varying both the scale type (4- and 5-point Likert scales) and the anchors (from performance quality to agreement intensity) are procedural strategies that can preserve the

TABLE 2 Constructs and items.

Construct	ID	Items	Mean	SD	Min	Max
Business digitalisation	DIG1	Our company's equipment and functions create good conditions for utilising digitality.	3.61	1.28	1	5
	DIG2	The processes of our company utilise a lot of digitality.	2.43	1.24	1	5
	DIG3	We utilise digitalisation in a key part of our products.	3.26	1.38	1	5
	DIG4	We use digitalisation as a key part of our services.	3.47	1.23	1	5
	DIG5	Our service portfolio includes a lot of digital services.	2.52	1.39	1	5
Economic sustainability (in relation to other similar companies in the industry)	ECON1	The profitability of our company is…	2.80	0.66	1	4
	ECON2	The economic sustainability of our company (operating in an economic balance that is not based on debts) is…	2.94	0.80	1	4
Environmental sustainability (in relation to other similar companies in the industry)	ENV	The environmental sustainability of our company (minimising environmental impact) is…	3.15	0.618	1	4

Source: Authors' own elaboration.

content validity of the questionnaire while minimising the risk of respondents using similar cognitive processes across different types of questions.

3.2.4 | Moderating variable

To account for the effect of firm size on the hypothesised relationships, we created a dummy variable based on the number of full-time employees in the companies. The definitions and classifications used in the context of MSMEs vary by country. In this study, we adhered to the proposal of both the OECD and European Commission, which classifies companies according to the number of employees as follows: microenterprises (fewer than 10 employees), small enterprises (10–49 employees), and medium-sized enterprises (50–249 employees) (Di Bella et al., 2023; OECD, 2023a).

Considering the above definition, our dummy variable takes the value of 1 if the business is a microenterprise (less than 10 employees), and zero otherwise (small or medium-sized). We made this decision considering that most of the companies included in this study were microenterprises, and due to their particular nature, it is not desirable to generalise the findings on SMEs to the smallest companies (Gherhes et al., 2016). Additionally, a dummy variable facilitates the analysis of moderating effects and subsequent interpretations. Furthermore, as suggested by Hair et al. (2022), moderation analyses provide a valuable approach for gaining a deeper understanding of data heterogeneity.

3.2.5 | Control variables

We included several control variables to mitigate potential biases arising from omitted variables. We controlled for the age of the firm, as younger firms are more likely to be positively influenced by digitalisation in their environmental management practices (Issah et al., 2024). We also included the customer base (B2B/B2C) as it has been used as a relevant control variable in sustainable business research (Nasiri, Saunila, Rantala, et al., 2022), considering its potential impact on digitalisation strategies and sustainability practices. Finally, we controlled for the firm's sector, distinguishing between production and services, as sector has been found to influence profitability (Boakye et al., 2020), and unlike production firms, service firms experience close interactions between products and processes (Prajogo, 2006).

3.3 | Data analysis technique

In quantitative research, the link between theoretical concepts and measurable entities that represent them is referred to as an epistemic relationship. While one out of the three variables included in our research model is directly measured by one indicator, two key constructs in our study (i.e., business digitalisation and economic sustainability) are composite variables measured by several indicators. Therefore, we used structural equation modelling with Partial Least Squares (PLS-SEM) to test the hypotheses, as PLS-SEM serves as a technique for estimating path models with composites and their relationships.

PLS-SEM is a variance-based SEM approach where the indicator variance is used to explain the model relationships and predict the dependent variable (Hair et al., 2022). Based on the guidelines of Hair et al. (2022), we decided to use PLS-SEM, considering the following factors:

a. The theoretical scope of the study: PLS-SEM is highly recommended when the research objective is oriented towards exploration rather than theory confirmation.

b. Data characteristics: PLS-SEM works efficiently with small sample sizes and different measurement scales. It is a non-parametric approach that is robust when handling non-normal data. We ensured that we fulfilled the minimum sample size requirements based on the guidelines of Nitzl (2016) to ensure that the results of our statistical procedure had adequate statistical relevance.
c. Measurement characteristics of the model: PLS-SEM allows researchers to use constructs that are measured using single- and multi-item measures from the same model.
d. Complexity of the model: PLS-SEM is a suitable choice for theoretical models that simultaneously examine mediating and moderating effects.
e. Estimation of the model: In terms of estimation, PLS-SEM offers higher levels of statistical power than other methods, such as Covariance-based Structural Equation Modelling (CB-SEM) (Hair et al., 2022).

3.4 | Non-response bias and common method bias

Considering the need to send reminders to participants during the application of the web-based questionnaire, non-response bias may represent a risk (Armstrong & Overton, 1977). We assessed the potential for non-response bias by comparing the answers of early and late respondents to all study items. The responses of 20 early participants were compared with those of 20 late participants. Based on the analysis of the variance test (at the 5% significance level), we concluded that no statistically significant differences existed between early and late respondents.

Furthermore, considering that the answers to the constructs used in this study were obtained from individuals who participated in a cross-sectional survey, it was imperative to comprehensively evaluate the possible impact of CMB. CMB typically occurs when dependent and independent variables are measured through the same survey, from the same source of information, and using a similar response method (Kock et al., 2021). To mitigate CMB in this study and following the recommendations provided by Podsakoff et al. (2003), we applied procedural and statistical techniques.

Regarding procedural controls, we adopted the following measures. We provided clear instructions to the participants regarding the context of the study and how the questions were to be answered. We also guaranteed the anonymity of the survey and the confidentiality of their responses. Third, we used clear and simple language in the questionnaire to avoid complex and ambiguous wording. Overall, we were meticulous about the length of the questionnaire, considering that short questionnaires, such as ours, can reduce fatigue among respondents and decrease the cognitive efforts to answer the questions (Kock et al., 2021).

With respect to the recommended statistical procedures, we performed Harman's single-factor test using SPSS 26.0, which revealed the existence of five primary factors that collectively explained 86.47% of the total variance. The largest factor accounted for 38.94% of this variability; however, it did not capture the majority of the covariation observed among the measures. Following Kock's (2015) recommendations, we performed a full collinearity test using SmartPLS 4.0.9.3. The findings from the analysis indicated that all variance inflation factors (VIF) remained below the prescribed threshold of 5, as suggested by Hair et al. (2019). Consequently, it can be deduced that CMB was not a noteworthy concern in this study.

4 | RESULTS

PLS path models rely on two sets of linear equations: the measurement model, which indicates the relationships between a construct and the observed indicators or manifest variables used to measure that construct; and the structural model, which specifies how the constructs are related to each other (Henseler et al., 2016). In the following paragraphs, we describe the evaluation of the structural and measurement models used in this study.

4.1 | Evaluation of the measurement model

The proposed research model follows a reflective structure in all constructs to measure unobservable variables, meaning that the constructs cause covariation in the indicators (Hair et al., 2022). Indicator reliability, internal consistency reliability, convergent validity, and discriminant validity are the criteria used to evaluate the reflective measurement models (Hair et al., 2022).

First, we examined the size of the outer loadings of the indicators (Table 3). Outer loadings indicate how much the associated indicators of a construct have in common (Hair et al., 2022). According to Hair et al. (2022), standardised outer loadings should be 0.708 or higher. All our indicators met this criterion.

Second, we evaluated the internal consistency reliability of the constructs (Table 3) by examining the Cronbach's alpha (Cα), Dijkstra–Henseler's rho (ρ_A) value, and composite reliability (CR) (Garcia-Pereyra et al., 2023). For our constructs, all internal consistency reliability criteria exceeded the values recommended by Hair et al. (2022), with values higher than 0.7 (Table 4).

To examine convergent validity, which measures the extent to which a given measure correlates positively with other measures within the same construct (Hair et al., 2022), we used the average variance extracted (AVE). The AVE values for the constructs exceeded the recommended threshold of 0.5 (Table 3), showing that the indicators in each construct had a high degree of communality.

Finally, we examined the discriminant validity of the proposed model. This is an indicator of the degree to which a construct is statistically and empirically different from the other constructs (Benitez et al., 2020). We used the heterotrait–monotrait (HTMT) ratio of the correlations to assess discriminant validity. Although the ideal threshold for HTMT values is debatable, the most conservative threshold considered in the literature is 0.85 (Hair et al., 2022). Our model did not have discriminant validity concerns because all values were considerably lower than 0.85 (Table 4).

TABLE 3 Indicator reliability, internal consistency reliability, and convergent validity.

Constructs	Indicators	Standardised outer loadings	Cronbach's alpha	Rho (ρ_A)	CR	AVE
Business digitalisation	DIG1	0.803	0.881	0.932	0.906	0.617
	DIG2	0.713				
	DIG3	0.861				
	DIG4	0.879				
	DIG5	0.775				
Economic sustainability	ECON1	0.886	0.757	0.761	0.891	0.804
	ECON2	0.903				
Environmental sustainability	ENV	1.000	n/a	n/a	n/a	n/a

Source: Authors' own elaboration based on PLS results.

TABLE 4 Discriminant validity (Heterotrait-monotrait [HTMT] ratio—Matrix).

Constructs	Business digitalisation	Economic sustainability
Business digitalisation		
Economic sustainability	0.173	
Environmental sustainability	0.205	0.310

Source: Authors' own elaboration based on PLS results.

4.2 | Evaluation of the structural model

We performed a two-tailed bootstrapping procedure with 10,000 subsamples to determine the statistical significance of the path coefficients. We also calculated the VIF to determine whether collinearity issues existed in the proposed model. To avoid substantial collinearity problems, Hair et al. (2022) suggested VIF values below 5. In our model, the highest value was 3.939, indicating that collinearity is not a serious concern.

Using bootstrapping, we evaluated the statistical significance of the hypothesised relationships among the constructs (Table 5), using *p*-values to assess significance levels. We also examined the coefficient of determination (R^2) to assess the explanatory power of the structural model. The R^2 analysis results indicate that the overall model accounted for 7% of the variance in environmental sustainability and 31% of the variance in economic sustainability.

According to the PLS-SEM results, the direct relationship between business digitalisation and the economic sustainability of a firm was not statistically significant; therefore, H1 is not supported. Conversely, business digitalisation was found to be positively associated with environmental sustainability (β =.45, p < .030), thus supporting H2. Similarly, we found that environmental sustainability is associated with economic sustainability, and the relationship between both variables is positive (β =.70, p < .000); therefore, H3 is supported.

Another key result of the hypotheses testing was that environmental sustainability positively mediates the relationship between business digitalisation and the economic sustainability of a company, thus supporting H4 (β =.31, p < .043). This finding indicates a full mediation model. While the direct effect is not significant (H1), the indirect effect is, implying that the overall effect of business digitalisation on the economic sustainability of a company is explained by environmental sustainability.

Regarding the effect of company size on the relationship between business digitalisation and economic sustainability (H5a), we found a positive and statistically significant association (β =0.31, p < .014). However, since the direct relationship between business digitalisation and economic sustainability was not found to be statistically significant, we avoid making inferences in this regard.

In the case of the relationship between business digitalisation and environmental sustainability, no statistically significant effect of company size was found (H5b), meaning that firm size does not influence the positive relationship between business digitalisation and environmental sustainability. However, we found that company size has a significant and negative moderating effect on the relationship between environmental sustainability and economic sustainability (β = −.63, p < .000), suggesting that this relationship is weaker or less favourable for microenterprises than for other companies. Therefore, H5c is supported.

5 | DISCUSSION

5.1 | Theoretical contributions

This study examines the direct relationship between business digitalisation and economic sustainability, while also investigating the potential mediating role of environmental sustainability. Additionally, this study investigates whether company size moderates these relationships, with a specific focus on whether microenterprises exhibit distinct patterns from larger companies.

This study makes two important contributions to the research on the intricate relationship between digitalisation, environmental sustainability, and economic sustainability. First, it challenges the hypothesised relationships by revealing a lack of significant association between business digitalisation and enterprises' economic sustainability. This suggests that increased digitalisation does not

TABLE 5 Results of the estimation of the structural model.

Structural paths	Original sample (β)	*t*-Values	Inference
H1: Business digitalisation- > Economic sustainability	−.30	1.51	Not supported
H2: Business digitalisation - > Environmental sustainability	.45**	2.18	Supported
H3: Environmental sustainability - > Economic sustainability	.70*	4.90	Supported
H4: Business digitalisation - > Environmental sustainability - > Economic sustainability	.31**	2.03	Supported
H5a: Size x Business digitalisation - > Economic sustainability	.58**	2.46	Supported
H5b: Size x Business digitalisation - > Environmental sustainability	−.34	1.34	Not supported
H5c: Size x Environmental sustainability - > Economic sustainability	−.63*	3.81	Supported

Source: Authors' own elaboration based on PLS-SEM analysis.
*$p < .01$; **$p < .05$.

necessarily lead to immediate or direct improvements in a company's economic outcomes, contradicting the prevailing views of previous studies (Bellakhal & Mouelhi, 2023; Martínez-Caro et al., 2020; Truant et al., 2021).

Nevertheless, consistent with our findings, only a few other studies have reported similar results. For example, research by Tsou and Chen (2021) conducted within Taiwanese financial companies also found no direct relationship between digital technology usage and the firm's financial and market performance. The authors suggested that factors such as digital transformation strategies and organisational innovation may influence this relationship.

Although our findings do not show a direct relationship between the level of digitalisation and greater economic performance, our study demonstrates that companies' efforts to digitalise their products, services, and processes positively impact their environmental sustainability. This finding aligns with Issah et al. (2024), suggesting that digitalisation acts as a catalyst for environmental sustainability and should be incorporated into firm-level strategies. Additionally, our results are consistent with Haq and Huo's (2023) study, which focused on small and medium enterprises (SMEs) in Pakistan and found that digitalisation can be a major driver in enhancing firms' environmental performance.

However, we not only demonstrated a positive association between digitalisation and a company's environmental sustainability but also found that this relationship may be mediated by environmental sustainability. One potential explanation for this outcome could be that the ability of digitalisation to generate a competitive advantage for firms depends on the extent to which it enhances environmental sustainability (Bendig et al., 2023). These findings are consistent with those of Broccardo et al. (2023), who found that within the context of Italian SMEs, digitalisation can positively affect companies' sustainability, which in turn contributes to improved profitability.

Our results are consistent with Nasiri, Saunila, and Ukko (2022), who concluded that companies must have the capability to comprehend and evaluate their current degree of digital orientation, intensity, and maturity to inform strategic decisions for financial success. Based on the RBV, this study advocates a strategic approach in which companies that leverage digitalisation to enhance environmental sustainability can indirectly contribute to their economic sustainability.

The second contribution of this study lies in examining the moderating role of business size. Our findings indicate that organisational context matters in the intricate relationship between digitalisation and the environmental and economic sustainability of the enterprises analysed. Specifically, our analysis revealed the negative moderating effect of business size on the relationship between environmental and economic sustainability. Although high levels of environmental sustainability generally lead to better economic outcomes, this relationship is much weaker for microenterprises compared to larger companies.

The empirical evidence from our study aligns with the findings of Roxas (2021), who analysed a sample of Vietnamese MSMEs (64.06% of which were microenterprises) and concluded that smaller firms tend to lag behind larger firms in terms of engaging in environmental management. Roxas (2021) suggested that smaller firms can address resource constraints through more intangible resources such as social capital to support their environmental management initiatives.

As evidenced in our study, microenterprises encounter various challenges in balancing the environmental aspects of sustainable development with economic sustainability. For instance, Jibril et al. (2024) explained that microenterprises face persistent constraints due to owners' perceptions that pursuing sustainability is expensive, leading firms to experience trade-offs between the social benefits and costs associated with a more sustainable business.

Moreover, the transition towards sustainability may be more challenging for established microbusinesses as they possess more limited technical, cognitive, and managerial resources than larger firms. This limitation contributes to heightened uncertainty regarding returns on sustainability investments and potential myopia concerning future market trends (Jibril et al., 2024).

In general, this study contributes to the intersection of information technology and strategic management literature. It demonstrates that digital capabilities optimise business processes, creating value for the firms (Eller et al., 2020). Additionally, a strategic orientation aligned with environmental and sustainability issues can translate into a competitive advantage for firms (Bendig et al., 2023). These findings are particularly relevant in the context of small businesses, which are often characterised by resource and capacity constraints.

5.2 | Managerial implications

Our results have important implications for small business managers and policymakers. The transition towards environmentally sustainable practices has been found to be more complex for small companies than for larger ones due to their limited financial resources and strong dependence on economic performance indicators to grow and survive (Karaeva et al., 2023). Thus, although economic benefits should not be the only motivation to improve their environmental practices, MSMEs must recognise the economic benefits of embracing environmental sustainability. If companies do not realise the business potential of environmental sustainability, their owners will lack incentives to prioritise environmental practices in their core business strategies.

In small business settings, many efforts have been made to emphasise the commercial benefits of environmental sustainability. However, studies have shown that owners often perceive environmental sustainability as difficult and expensive to implement (Revell & Blackburn, 2007), leading to a high level of scepticism among small business owners and managers regarding its business benefits (Revell, 2010).

Previous research suggests that for smaller businesses to benefit economically from sustainable management, owners and entrepreneurs must strategically rethink their approach to sustainability (Cantele & Zardini, 2018). This involves considering not only a win-win relationship in economic terms but also the benefits they can achieve in terms of business reputation and meeting customer expectations (Cantele & Zardini, 2018).

5.3 | Societal implications

Companies are expected to increase their concern about the natural environment and drastically reduce the environmental impacts derived from their operations (Lucato et al., 2017), reshaping the way business is conducted. We consider that the focus on microenterprises is extremely relevant given that these businesses hold significant potential to advance twin transitions in both the digital and environmental domains. Supporting these firms in their journey towards sustainability by encouraging the adoption of innovative green solutions has the potential to yield significant global environmental benefits (Pronti et al., 2024).

Given that our findings suggest a diminished capacity of microenterprises to convert their environmental efforts into improved economic outcomes, there is a critical need for tailored support mechanisms specifically designed to address the distinct challenges faced by these small entities. Such support can take the form of grants, subsidies, or tax incentives designed to facilitate the adoption of sustainable environmental practices. Providing technical assistance and advisory services is vital to microenterprises. Policymakers should also foster partnerships and collaborative innovation between microenterprises and larger companies to enable the mutual exchange of knowledge and resources that can drive sustainable growth.

6 | CONCLUSION

One of the main conclusions drawn from this study is that digitalising a business might not directly lead to improved economic sustainability. However, when a company focuses on improving its environmental sustainability, the positive effects of digitalisation on economic sustainability become more apparent. Given the owner-manager-entrepreneur centrism in microenterprises, future research should examine how individual owner characteristics interact with company-level factors. This approach deepens our understanding of the relationship between digitalisation and the environmental and economic sustainability of small companies.

Finally, several important limitations of this study should be considered. First, the sample size was relatively small. However, we ensured that the minimum sample size necessary to perform PLS-SEM analysis was met. We also found that 62% of our companies are microenterprises. Collecting data on microenterprises is helpful for advancing research in this context, given the current absence of internationally comparable empirical data on the digitalisation efforts undertaken by microenterprises. Despite the fact that microenterprises constitute approximately 90% of the business population within OECD countries, there is a notable deficiency in available information concerning their digitalisation endeavours (OECD, 2021b).

Another potential limitation of this study is social desirability bias. As proposed by Heras-Saizarbitoria et al. (2020), environmental sustainability measures primarily based on managers' perceptions or opinions may be influenced by social desirability or self-reporting bias. However, in line with Wang et al. (2023), we implemented several strategies to mitigate the influence of social desirability bias and encouraged participants to provide honest perspectives. These strategies included guaranteeing anonymity and confidentiality for participants and requesting answers from their firms' perspectives rather than expressing personal opinions (Wang et al., 2023).

Considering that this study provides only a snapshot in time, longitudinal studies are needed to address endogeneity concerns in the proposed research model. Endogeneity can compromise key conditions for claiming causality (Zhang et al., 2022). Therefore, the relationships suggested should be interpreted more as robust correlations rather than causal links. However, we managed the observed heterogeneity through moderation analysis, which, as outlined by Guenther et al. (2023), can help alleviate endogeneity issues. Additionally, we incorporated theoretically relevant control variables into our research model to reduce omitted variable bias (Proksch et al., 2021).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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