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**Linking Digital Transformation, Sustainability, and
Internationalization: A Multilevel Investigation of Firm
Competitiveness**

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*To my family,
for always being there.*

*To Federico,
my silent strength through it all.*

*To Alexia, Michela, Gioele, Giulio, and Fatima,
for brightening the path and helping me through.*

*To my Supervisor, Professor Maria Chiarvesio,
for believing in my work.*

*To everyone I did not mention by name,
for everything you have done for me.*

Thank you for being part of this journey.

*Alla mia famiglia,
per esserci sempre stata.*

*A Federico,
la mia forza e la mia sicurezza.*

*Ad Alexia, Michela, Gioele, Giulio, e Fatima,
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Grazie di essere stati parte di questo viaggio.

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SUMMARY

The convergence of digital transformation, sustainability, and internationalization is redefining the foundations of global competitiveness. As firms navigate accelerating technological disruption, environmental urgency, and geopolitical complexity, their ability to properly integrate digital and sustainable strategies across borders has become an important source of competitive advantage. Yet, despite the growing attention to each of these dimensions independently, research remains fragmented and lacks a unified understanding of how they interact with one another. This dissertation addresses this gap through a multilevel investigation that connects conceptual synthesis, qualitative inquiry, and quantitative testing to explain how firms leverage the digital and green transitions to strengthen their international competitiveness. The work is organized into three interconnected essays, each offering a distinct yet complementary contribution to this overarching theme.

The first essay systematizes the field through a comprehensive review of the literature, revealing five main research streams and exposing critical blind spots in the intersection of digitalization, sustainability, and internationalization. The second essay explores these dynamics empirically through multiple case studies of Italian manufacturing small- and medium-sized enterprises (SMEs), identifying four distinct strategic configurations – digital transformation-led, sustainability-led, parallel and integrated – that represent the contingent pathways through which resource alignment and contextual fit drive international performance. The third essay quantitatively tests the relationship among these three strategies using survey data from 239 exporting manufacturers, demonstrating that Industry 4.0 adoption and sustainability practices are mutually reinforcing, with sustainability partially mediating the relationship between digitalization and international performance.

Together, the research advances an integrative framework linking digital and sustainable transformations with firms' international strategies. The dissertation contributes to the fields of

international business, strategic management, and sustainability studies by clarifying the strategic and competitive implications of pursuing digitalization and sustainability in an international context. It offers both theoretical synthesis and actionable insights for managers and policymakers seeking to transform twin transitions into enduring sources of global competitiveness.

RIASSUNTO

La convergenza tra trasformazione digitale, sostenibilità e internazionalizzazione sta ridefinendo le basi della competitività globale. In un contesto caratterizzato da rapidi cambiamenti tecnologici, una crescente attenzione alle sfide ambientali e complessità geopolitiche, la capacità delle imprese di integrare strategie digitali e sostenibili su scala internazionale è diventata una fonte rilevante di vantaggio competitivo. Tuttavia, nonostante il crescente interesse per ciascuna di queste dimensioni, la ricerca rimane frammentata e manca di una visione integrata delle loro interazioni. La presente tesi affronta questa lacuna attraverso un'indagine multilivello che combina sintesi teorica, esplorazione qualitativa e verifica quantitativa, con l'obiettivo di comprendere come le imprese utilizzino la transizione digitale e verde per rafforzare la propria competitività internazionale. Il lavoro è articolato in tre saggi tra loro collegati, ciascuno dei quali offre un contributo scientifico complementare al tema centrale.

Il primo saggio propone una revisione sistematica della letteratura, individuando cinque principali filoni di ricerca e mettendo in luce importanti gap nell'analisi delle interconnessioni tra digitalizzazione, sostenibilità e internazionalizzazione. Il secondo saggio esplora questi aspetti attraverso nove casi studio di piccole e medie imprese (PMI) manifatturiere italiane, identificando quattro configurazioni strategiche – orientata alla trasformazione digitale, orientata alla sostenibilità, parallela e integrata – che descrivono i diversi percorsi attraverso cui l'allineamento delle risorse e la coerenza con il contesto favoriscono la performance internazionale. Il terzo saggio analizza, attraverso una metodologia quantitativa, la relazione tra queste tre strategie su un campione di 239 imprese esportatrici, dimostrando che l'adozione delle tecnologie dell'Industria 4.0 e le pratiche di sostenibilità si rafforzano reciprocamente, e che la sostenibilità media parzialmente la relazione tra digitalizzazione e risultati internazionali.

Nel complesso, la ricerca propone un quadro integrato che collega la trasformazione digitale e sostenibile alle strategie di internazionalizzazione delle imprese. La tesi contribuisce

agli ambiti di ricerca del business internazionale, del management strategico e della sostenibilità, offrendo una chiave di lettura utile a comprendere le implicazioni strategiche e competitive derivanti dall'integrazione di pratiche di digitalizzazione e sostenibilità in un contesto internazionale. Infine, offre sia una sintesi teorica sia indicazioni operative per manager e decisori politici che mirano a trasformare le twin transitions in fonti durature di competitività.

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INTRODUCTION

1. Framing of the Dissertation

In an era of technological disruption and mounting environmental challenges, firms face the dual imperative of digital transformation and sustainability. The former is understood as a strategic process aimed at improving organizational capabilities by triggering significant structural changes through the convergence of information, computing, and connectivity technologies (Vial, 2021). This transformation has been recently operationalized through the adoption of Industry 4.0 technologies, such as artificial intelligence (AI), the Internet of Things (IoT), and automation, which are fundamentally reshaping how organizations create value, structure their operations, and compete internationally (Culot et al., 2020; Luo & Zahra, 2023; Matt et al., 2023). At the same time, the escalating urgency of climate change and social inequality has elevated sustainability from a peripheral concern to a defining principle of corporate strategy, embodied in frameworks such as the triple bottom line (Elkington, 1998) and the United Nations Sustainable Development Goals (UN DESA, 2023). However, for firms to effectively navigate this global challenge, these normative ideals must be translated into concrete organizational behaviors. Accordingly, this dissertation moves beyond broad conceptualizations to address sustainability as a set of corporate practices. Sustainability is thus defined as the strategic integration of environmental and social concerns into core business operations, manifesting through specific actions such as pollution reduction, resource efficiency, and social equity initiatives (Bansal, 2005; Eccles et al., 2014).

These forces are converging in what policymakers and scholars increasingly describe as the twin transitions, the simultaneous drive toward digitalization and sustainability as cornerstones of future competitiveness (Rehman et al., 2023; Tabares et al., 2025). The global economy's volatility, uncertainty, complexity, and ambiguity (VUCA) (Buckley, 2023; Hallioui et al.,

2022) make these transitions not optional, but essential for survival. Firms must simultaneously digitize operations, decarbonize value chains, and operate in increasingly interconnected yet fragmented global markets (Ciulli & Kolk, 2023).

In the realm of international business (IB), the intersection of digital transformation, sustainability, and internationalization represents both a pressing managerial challenge and a theoretical frontier. In this context, internationalization is conceptualized primarily as the process of outward commercial expansion and the resulting competitive performance in foreign markets (Knight & Cavusgil, 2004). Within this evolving competitive landscape, digitalization reshapes global value chains by enhancing transparency, traceability, and coordination (Luo & Zahra, 2023; Romanello & Veglio, 2022; Strange & Zucchella, 2017). Sustainability introduces new constraints and opportunities that redefine legitimacy and competitiveness across markets (Broccardo et al., 2023; Guo et al., 2024). Yet, despite the growing recognition that these two dimensions are intertwined, academic research has not fully captured how firms integrate digital and sustainable strategies to achieve international success.

Existing research has addressed these dynamics through fragmented lenses. Studies on digitalization and sustainability explore how technologies enable environmentally responsible practices (Bag & Pretorius, 2022; Del Río Castro et al., 2021). Others focus on digitalization and internationalization, emphasizing how Industry 4.0 technologies support market entry, reshoring, and network reconfigurations (Autio et al., 2021; Luo & Zahra, 2023). A third stream examines sustainability and internationalization, focusing on corporate social responsibility (CSR), green innovation, and stakeholder engagement in global markets (Gómez-Bolaños et al., 2022; Van Tulder et al., 2021). However, the literature rarely explores the triadic interplay of these three domains within the same analytical framework (Ciulli & Kolk, 2023; Denicolai et al., 2021). Existing studies remain methodologically scattered and only a few examine how

digital and sustainability transformations jointly shape international performance, or how firms align these transitions under different strategic and institutional conditions (Ghauri et al., 2021). Empirically, two major gaps persist. First, existing evidence predominantly focuses on large multinational enterprises (MNEs) (Dias Lopes et al., 2023; Srinivasan & Eden, 2021), overlooking the experiences of small- and medium-sized enterprises (SMEs). SMEs face distinct constraints in financial and technological resources, yet they are central to achieving both digital and green transitions (Denicolai et al., 2021; Suchek et al., 2023; Valero-Gil et al., 2024). Second, while quantitative research often demonstrates that Industry 4.0 technology and sustainability practices independently enhance performance (Bettiol et al., 2022; Gupta & Gupta, 2020), the mechanisms linking them remain insufficiently tested. From a theoretical standpoint, the field lacks an integrated lens that can explain how firms reconcile the dual pressures of digitalization and sustainability while operating internationally (Ocelík et al., 2023).

Recent scholarship has begun to bridge these gaps by highlighting the synergies between digitalization, sustainability, and internationalization (e.g., Denicolai et al., 2021; Le and Vu, 2024). Digital technologies are increasingly seen as enablers of sustainable innovation, enhancing transparency and resource efficiency in global operations (Ferreira et al., 2023; Wang & Ramsey, 2024). Conversely, sustainability imperatives drive technological adoption and legitimacy in international markets (Li & Sun, 2024; Ma et al., 2024). Policy frameworks such as the European Green Deal and the twin transitions further underline their mutual dependence (Rehman et al., 2023; Sharma et al., 2022). Yet much remains to be understood about how these interdependencies play out at the firm level. This dissertation contributes to this emerging field by offering a multi-level investigation that integrates conceptual synthesis, qualitative exploration, and quantitative validation to explain how digital transformation and sustainability strategies interact to shape firms' international competitiveness, particularly within the underexplored SME context.

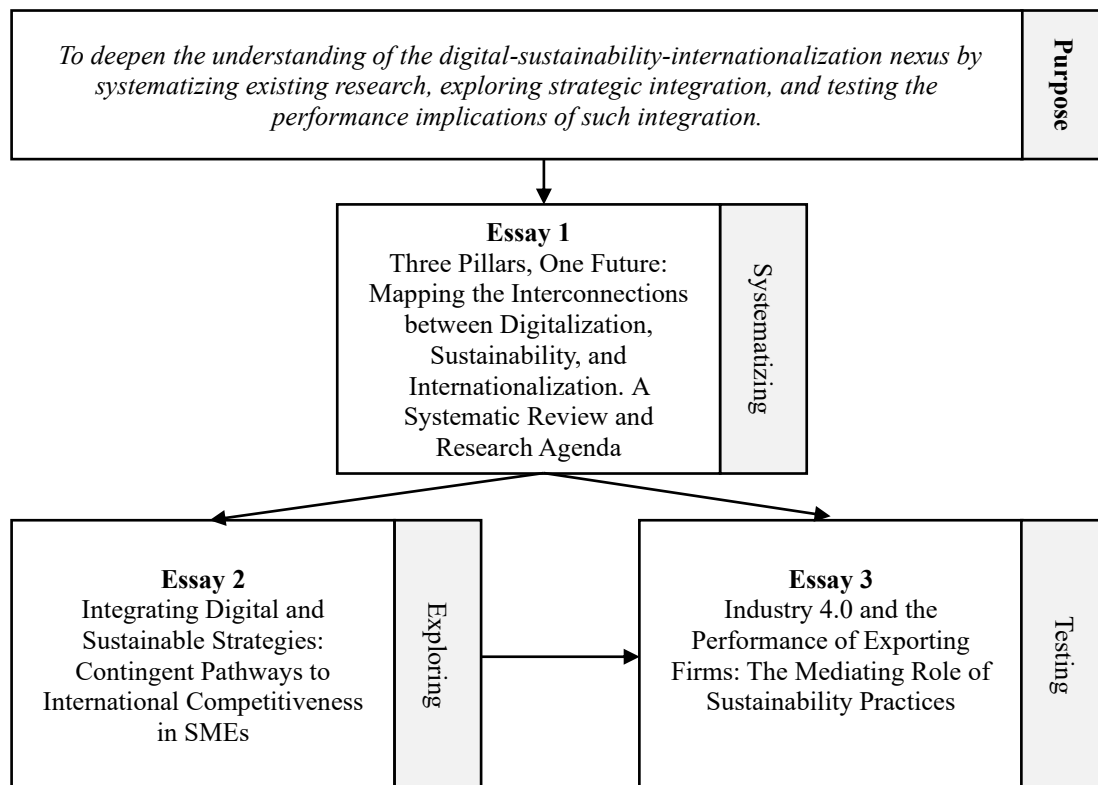
2. Dissertation Purpose and Research Questions

The primary objective of this dissertation is to advance the understanding of how firms integrate digital transformation and sustainability strategies to enhance their international competitiveness. Although the themes of digitalization, sustainability, and internationalization have each received extensive scholarly attention, the interconnections among them remain insufficiently explored (Ocelík et al., 2023). Existing research largely investigates dyadic relationships (e.g., Autio et al., 2021; Bag and Pretorius, 2022; Gómez-Bolaños et al., 2022) without developing an integrated framework that explains how firms combine these dimensions to achieve superior performance across borders.

This dissertation seeks to address these gaps by systematically organizing and extending knowledge on the interrelation between digitalization, sustainability, and internationalization, and by empirically analyzing the mechanisms and contextual factors through which this integration contributes to firms' international competitive advantage. By combining conceptual, qualitative, and quantitative approaches, the dissertation provides a multi-level understanding of how firms navigate and leverage the convergence of digital and sustainable transformation within an IB context. Specifically:

The purpose of this dissertation is to deepen the understanding of the digital-sustainability-internationalization nexus by systematizing existing research, exploring strategic integration, and testing the performance implications of such integration.

To fulfill this purpose, the dissertation comprises three interconnected essays, each exploring a specific facet of the overall research theme (see Figure 1.1).

Figure 1.1. Dissertation structure, purpose, and essays' interconnectedness

Essay 1: The first essay establishes the conceptual foundation of this dissertation by consolidating and synthesizing the extant literature at the intersection of these three domains. Despite the rapid expansion of research in digital transformation, sustainability, and IB, scholarly work remains fragmented and dispersed across fields, offering a limited cumulative understanding of how these transformations jointly influence firm competitiveness (Ocelík et al., 2023).

To address this fragmentation, the essay conducts a systematic literature review of seventy peer-reviewed articles published between 2011 and 2024, following the PRISMA guidelines (Page et al., 2021). It identifies five main thematic clusters that characterize the field – digitalization as a driver of sustainability in the IB context, the mediating and moderating roles of internationalization in the digital-sustainability nexus, digitalization as a catalyst for internationalization and the effect of sustainability, internationalization driving the integration

of digitalization and sustainability, and sustainability's influence on digitalization and internationalization. Based on this analysis, the essay provides a structured synthesis of the fragmented literature on digital transformation, sustainability, and internationalization, highlighting key complementarities and contradictions in how firms navigate global challenges. Additionally, it advances the field by proposing a forward-looking research agenda that addresses both theoretical gaps and practical implications for firms operating in complex, interdependent environments.

RQ1: What are the main themes and connections emerging from the literature examining the relationship between digital transformation, sustainability, and internationalization at the firm level?

RQ2: What avenues for future research emerge from studies that concurrently address these three domains?

Essay 2: The second essay builds upon the conceptual insights from the literature review to explore empirically how firms combine digital and sustainability initiatives in practice to achieve international competitiveness. SMEs face the dual challenge of limited resources and increasing external pressures (Valero-Gil et al., 2024). To investigate how these firms approach digital-sustainability integration, the study employs a qualitative multiple-case design involving nine Italian manufacturing SMEs operating in international markets.

Drawing on contingency theory (Donaldson, 2001; Lawrence & Lorsch, 1967), the essay examines how the alignment between internal resources, industry characteristics, and market expectations shapes firms' digital sustainability strategies. The findings reveal four distinct strategic configurations – digital transformation-led, where technological upgrading drives international competitiveness; sustainability-led, where environmental and social objectives represent the cornerstone of firms' strategies and the core driver of international

success; parallel, where the two strategies are present but evolve independently; and integrated, where digital and sustainability dimensions are pursued simultaneously and synergistically to maintain a competitive advantage in international markets. The essay contributes a contingency-based typology explaining how contextual fit determines the success of digital-sustainability integration in enhancing the international competitiveness of exporting SMEs.

RQ: How do SMEs navigate different pathways of integrating digital transformation and sustainability, and how do these pathways influence their international competitiveness?

Essay 3: The third essay extends the investigation by quantitatively testing the mechanisms linking digitalization, sustainability, and international performance. Building on the resource-based view (Barney, 1991; Penrose, 1959; Peteraf, 1993), it conceptualizes Industry 4.0 technologies and sustainability practices as complementary strategic resources that, when jointly implemented, generate sustainable competitive advantage.

Using survey data from 239 Italian exporting manufacturers, the study employs multivariate regression and mediation analysis to examine how Industry 4.0 adoption affects international financial and operational performance, and whether sustainability practices mediate this relationship. The results demonstrate that both Industry 4.0 and sustainability practices exert positive effects on performance, with sustainability partially mediating the digitalization-performance link. These findings confirm that digital and sustainable transformations are mutually reinforcing rather than competing strategic imperatives (Denicolai et al., 2021). The essay contributes robust empirical evidence supporting the synergistic potential of these two competitive strategies and provides actionable insights for managers and policymakers seeking to align digital investment with sustainability objectives.

RQ: To what extent do Industry 4.0 technologies and sustainability practices affect firms' international performance, and do sustainability practices mediate this relationship?

The three essays are at different stages of advancement and dissemination. Essay 1 was presented at the SIM Annual Conference in Florence (September 2023) and at the Sinergie – SIMA Conference in Parma (June 2024) and is currently under review in an international journal. Essay 2, still a work in progress, was presented at the EURAM Conference in Florence (June 2025) and at the 85th AoM Annual Meeting in Copenhagen (July 2025). Essay 3 has been accepted for the Journal of International Business Studies Paper Development Workshop at the EIBA Annual Conference, taking place in Athens (December 2025), and is currently undergoing its first round of revision in another international outlet. Together, the essays contribute to the IB debate on how firms can strategically and competitively leverage digital and sustainable transformation to achieve an enduring competitive advantage.

3. Structure of the Dissertation

The remainder of this dissertation is structured into three essays and a concluding section that develop and connect the key arguments outlined in this introduction. Each contributes to a comprehensive exploration of the digital-sustainability-internationalization nexus, progressing from the conceptual framing of the digital-sustainability-internationalization nexus to its empirical investigation through qualitative and quantitative analyses, and ultimately to the synthesis of theoretical and managerial insights.

Essay 1 offers a systematic review of existing literature at the intersection of digital transformation, sustainability, and IB. By mapping and critically assessing prior research, it

establishes conceptual foundations of the dissertation and identifies the main thematic patterns, complementarities, and research gaps that guide the subsequent empirical works.

Essay 2 transitions from theory to empirical exploration through a qualitative, multiple-case study of Italian manufacturing SMEs. The study examines how firms with different strategic orientations and resource endowments integrate digital and sustainability dimensions in their internationalization processes. Through this analysis, a typology of strategic configurations is developed, illustrating the diversity of pathways through which SMEs achieve international competitiveness.

Essay 3 extends this investigation through a quantitative analysis based on survey data from Italian exporting manufacturers. Grounded in the resource-based view, it empirically tests the relationships among Industry 4.0 adoption, sustainability practices, and international performance, highlighting the mediating role of sustainability and the synergies that emerge when digital and sustainable strategies are jointly pursued.

Finally, the conclusions summarize the dissertation by drawing together the main theoretical, empirical, and practical contributions, discussing the broader implications for IB scholarship and managerial practice, and outlining promising avenues for future research.

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Essay 1

THREE PILLARS, ONE FUTURE: MAPPING THE INTERCONNECTIONS BETWEEN DIGITALIZATION, SUSTAINABILITY, AND INTERNATIONALIZATION. A SYSTEMATIC REVIEW AND RESEARCH AGENDA

Abstract

Digital transformation, sustainability, and internationalization have emerged as paramount challenges and opportunities for contemporary corporate competitiveness. While existing research has extensively explored the dyadic relationships among these dimensions, a growing body of literature is now examining their complex interplay. This study presents a systematic review of 70 high-quality journal articles, providing an in-depth thematic analysis of how these three pillars of value creation interact. Our analysis identifies five key research clusters. Notably, existing research predominantly positions digitalization as a catalyst for advancing sustainability in international contexts. Further streams explore the mediating and moderating role of internationalization in the digitalization-sustainability nexus, how digital innovation shapes internationalization strategies and how sustainability affects this process, the role of internationalization in driving digital and sustainable practices, and sustainability as a driver of both internationalization and digital transformation. By mapping these interconnections, this review synthesizes the state of current research and uncovers critical gaps, outlining promising avenues for future inquiry aimed at fostering a more holistic integration of digital, sustainable, and international strategies.

Keywords: *Digital Transformation; Industry 4.0; Sustainability; Internationalization; Literature Review; SDG*

1. Introduction

In today's global economy, firms operate within an increasingly complex landscape shaped by overlapping technological, environmental, and geopolitical disruptions. Digital transformation – the integration of advanced digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), and automation to reconfigure business models, enhance operational

efficiency, and impact customer relationships – has accelerated rapidly, reshaping the foundations of competition, value creation, and international expansion (Rüßmann et al. 2015; Culot et al. 2020; Matt et al. 2023; Luo and Zahra 2023) . At the same time, growing urgency around climate change, social responsibility, and regulatory pressure has pushed sustainability from a peripheral concern to a strategic imperative (Van Tulder et al. 2021; IPCC 2023). As a result, firms are increasingly expected and encouraged by stakeholders to align their operations with long-term environmental, social, and economic goals to achieve better performance (Ilyas and Osiyevskyy 2022), guided by frameworks such as the triple bottom line and the United Nations Sustainable Development Goals (SDGs) (Elkington 1997; George et al. 2021). These developments unfold in a context marked by heightened volatility, uncertainty, complexity, and ambiguity – the so-called VUCA world (Halloui et al. 2022; Buckley 2023) – making it increasingly difficult for firms to chart coherent international strategies and reconfigure their resource and capabilities while remaining responsive in a highly competitive global landscape (Jantunen 2005).

Against this backdrop, the convergence of digital transformation, sustainability, and internationalization is emerging not as a mere theoretical exercise but as a practical necessity. Firms are simultaneously expected to digitize operations, reduce environmental footprints, and navigate international markets, often without a clear roadmap of how these goals interact, reinforce, or constrain each other (Ciulli and Kolk 2023). Reflecting this growing interest, recent studies have begun to examine the intersections between these domains. However, much of this work has remained focused on dyadic intersections – such as between digitalization and sustainability (e.g., Bag and Pretorius, 2022; Del Río Castro et al., 2021), digitalization and internationalization (e.g., Autio et al. 2021; Luo and Zahra 2023; Chatterjee et al. 2023), and sustainability and internationalization (e.g., Gómez-Bolaños et al., 2022; Van Tulder et al., 2021). While these studies offer valuable insights, research that holistically examines how these

three forces interact at the firm level remains sparse and fragmented (Ghauri et al. 2021; Luo and Zahra 2023; Ciulli and Kolk 2023).

The need for integrating digital transformation, sustainability, and internationalization is further stressed by emerging business practices and policy frameworks. Concepts such as the twin transitions, which highlight the parallel imperatives of digital and green transformation (Brueck 2024), have gained traction across Europe and beyond as guiding frameworks for economic and industrial policy (European Commission 2022; Montresor and Vezzani 2023). Similarly, the effectiveness of global coordination and interoperability, longstanding principles of international business (IB), are being re-evaluated in light of emerging technologies and changing sustainability norms (Zhan 2021; Niehoff et al. 2022). Despite these developments, there remains a limited understanding of how firms are integrating these transitions in practice, what synergies or trade-offs emerge, and what strategic responses are proving most effective. For instance, while digital technologies are often assumed to enable sustainability (Chopra et al. 2024), their impact depends on contextual factors, including organizational strategy, governance, and institutional environments (Beltrami et al. 2021; Broccardo et al. 2023). Similarly, internationalization has been associated with both sustainability-driven innovation and exploitative practices, particularly among multinational enterprises (MNEs) embedded in global value chains (GVCs) (Gómez-Bolaños et al. 2022; Ocelík et al. 2023).

This study addresses these gaps by conducting a systematic literature review (SLR) that examines the intersection of digital transformation, sustainability, and internationalization at the firm level. To guide the analysis, we frame our review around two guiding research questions.

RQ1: What are the main themes and connections emerging from the literature examining the relationship between digital transformation, sustainability, and internationalization at the firm level?

RQ2: What avenues for future research emerge from studies that concurrently address these three domains?

Drawing on a multi-stage screening process grounded in established SLR protocols (Massaro et al. 2016; Paul and Criado 2020), we systematically analyze 70 peer-reviewed journal articles. Our approach combines a descriptive overview with an in-depth thematic synthesis, resulting in an integrative framework that clarifies the current state of research and identifies where conceptual integration or empirical work is lacking.

This review offers three focal contributions. First, it provides a structured synthesis of a rapidly expanding but fragmented body of knowledge, bringing together insights from digital transformation (e.g. Autio et al., 2021), sustainability in IB (e.g., Zhao et al., 2024), and global strategy (e.g., Van Tulder et al., 2021). Second, it uncovers overlooked complementarities and contradictions across the digital-sustainable-internationalization nexus – for example, how digital capabilities may both enable and constrain sustainable international growth, or how firms reconcile global scale with local digitalization and sustainability challenges. Third, it presents a forward-looking research agenda rooted in practical relevance, pointing to questions that are not only theoretically significant but also critical for firms striving to remain competitive and responsible in a complex and interdependent world (Buckley and Casson 2021).

2. Methods

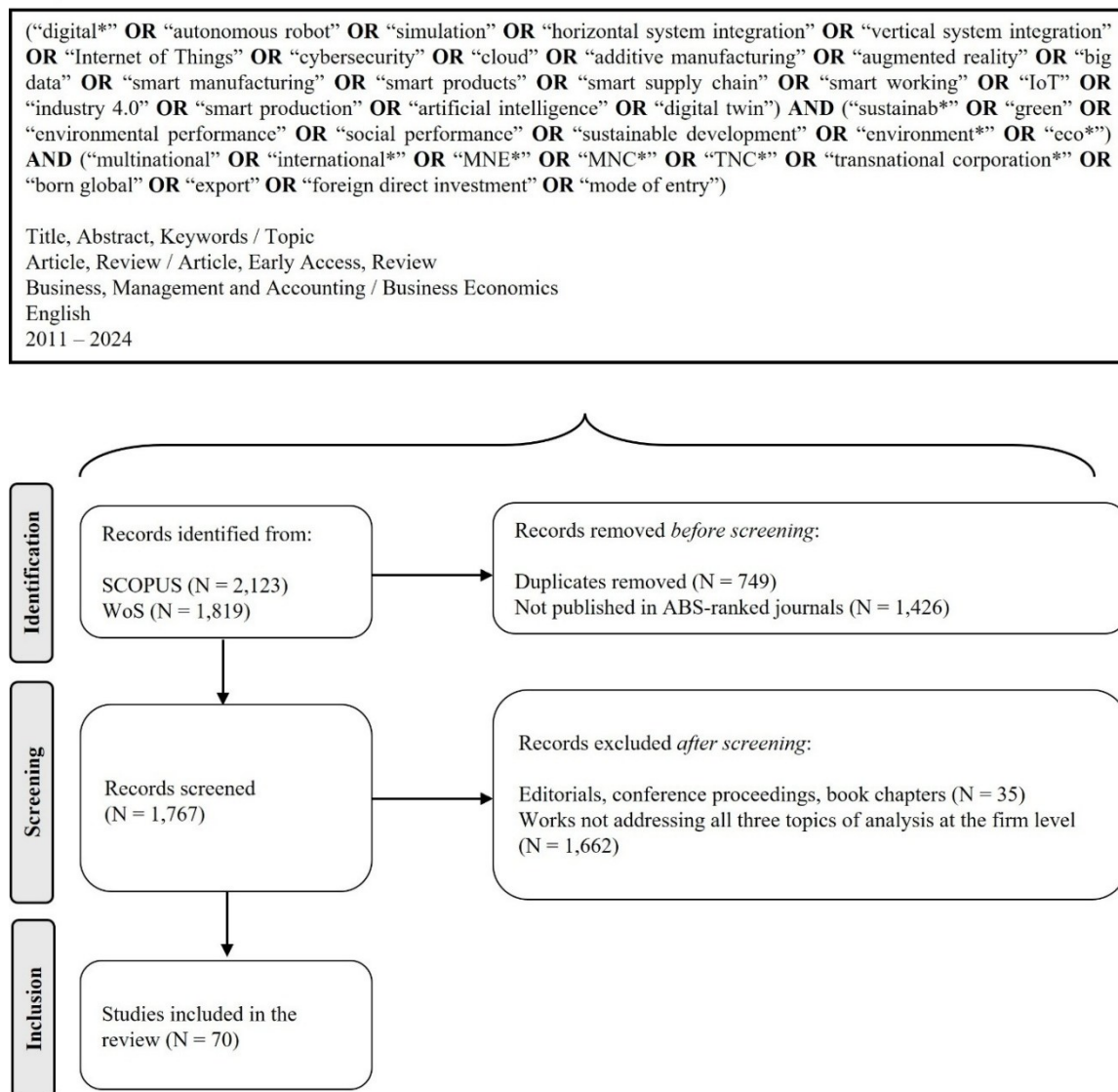
2.1. Review Method

The study adopts a SLR approach (Snyder 2019) to examine how the interplay between digital transformation, sustainability, and internationalization has been explored in the business and management literature. The objective was not merely to map existing contributions but to

develop a deeper understanding of how these three domains have been conceptually and empirically integrated at the firm level.

The PRISMA guidelines (Page et al. 2021) were adopted to report the review process with transparency and structure. For the search and screening steps, we followed the structured approach proposed by Gusenbauer and Gauster (2025). This helped us carefully choose databases, define search strategies, apply quality standards, and reduce bias. The process followed four main stages – identification, screening, eligibility assessment, and inclusion (see Figure 2.1).

Figure 2.1. PRISMA 2020 flow diagram for new systematic reviews



2.2. Step 1: Identification

The initial identification phase involved a comprehensive search of two leading bibliographic databases – Scopus and the Web of Science (WoS) Core Collection. These are widely recognized for their extensive coverage of academic journals across disciplines, making them particularly suitable for high-quality literature reviews (Rosa et al., 2020). To construct a robust search query, we identified three conceptual clusters of keywords aligned with the themes of digital transformation, sustainability, and internationalization. Keywords for digital transformation were drawn from prior academic work (Frank et al. 2019) and practitioner literature (Rüßmann et al. 2015), while sustainability-related terms were selected based on the contributions of Sarkis and Zhu (2018) and Beltrami et al. (2021). Finally, to capture the full scope of internationalization phenomena, we included broad terms (Fan et al. 2021) related to traditional MNEs (Ocelík et al. 2023), entry modes (Cuervo-Cazurra et al., 2023), and new internationalization phenomena (Romanello and Chiarvesio 2019; Paul and Rosado-Serrano 2019).

The search was conducted using Boolean logic (AND/OR) to combine the three clusters. To ensure quality and relevance, we restricted the results to articles and reviews published in English, within the business, management, and accounting subject areas, from January 2011 to October 2024. The start date was selected to reflect the rise of digital transformation in business practice and policy following the emergence of Industry 4.0 (Frank et al. 2019) and the growing academic focus on sustainability after the 2012 United Nations Conference on Sustainable Development in Rio de Janeiro (United Nations 2012). Only papers published in journals listed in the 2024 Academic Journal Guide (CABS 2021) were considered. This ensured a focus on academic quality and enabled the retrieval of the “best available evidence” (Durach et al. 2017) while preserving the breadth of emerging contributions.

2.3. Step 2: Screening

The search yielded 2,123 documents from Scopus and 1,819 from WoS Core Collection. The records retrieved from the two databases were merged into a single dataset, and duplicates were removed. Subsequently, non-journal publications (e.g., conference proceedings, editorials, book chapters) were excluded. We then filtered out papers not published in ABS-ranked journals, resulting in a dataset of 1,767 unique documents.

The analysis and data processing were conducted using Microsoft Excel and IBM SPSS, which, in the initial phase, were employed to identify ABS-ranked papers and remove duplicates. Given the complexity of the topic, an attentive and systematic exclusion process was performed, guided by predefined criteria aligned with the research aims (Petticrew and Roberts 2008).

A manual screening of titles and abstracts was conducted to determine the relevance of each article. Documents were retained only if they addressed all three thematic domains simultaneously – digital transformation, sustainability, and internationalization – and approached the topic from a firm-level perspective. Studies that focused extensively on only one or two of the domains, or that centered on policy, societal, or purely industry-level issues, were excluded. Where abstracts did not provide sufficient clarity, full texts were reviewed to assess the study's fit with the inclusion criteria.

2.4. Step 3: Eligibility assessment

Applying the predefined exclusion and inclusion criteria, we identified 70 relevant papers from the initial dataset. These studies were selected based on their clear and simultaneous focus on different dimensions of digital transformation, sustainability, and internationalization from a firm-level perspective. The substantial reduction from the initial corpus is attributable to the stringent requirement that all three dimensions be addressed in an integrated manner within the

same study. Papers were excluded if they examined these domains separately or lacked a firm-level analytical lens. This rigorous filtering process ensured that only the most pertinent and conceptually aligned works were retained for in-depth analysis.

The selected articles were then systematically analyzed, coded, and classified. In addition to the bibliographic and metadata retrieved from Scopus and WoS, we incorporated a broader set of variables to facilitate deeper analysis and interpretation. Specifically, for each paper, we recorded the type of research (theoretical, empirical, or literature review), the methodology adopted (qualitative, quantitative, or mixed-methods), the main research findings, the unit of analysis, the digitalization topic addressed (e.g., adoption of digital technologies, business model innovation, digital capabilities), the sustainability focus (e.g., environmental, social, or integrated sustainability approaches), the internationalization dimension (e.g., market entry, global operations, international performance), the nature of the interconnection among the three focal areas, future research avenues proposed by the authors, country or regional context of the study, hypotheses or propositions developed (when applicable), and the theoretical lens or framework employed. This approach enabled us to move beyond surface-level thematic analysis and examine how different dimensions were conceptualized and empirically explored across the literature.

2.5. Step 4: Inclusion and Thematic Analysis

The final phase of the review involved synthesizing the selected 70 articles into a coherent analytical framework. This was achieved through a thematic analysis, grounded in deep engagement with the full content of each article. The objective was to identify recurring patterns, conceptual contributions, and analytical approaches while also uncovering gaps and underexplored areas within the intersection of digital transformation, sustainability, and internationalization.

The thematic synthesis was conducted inductively, through a process of iterative and comparative reading (Baltazar et al. 2025). As emerging themes became evident, they were progressively refined to capture both the substantive insights of each study and the nuanced ways in which the three focal dimensions interacted. Specifically, the assignment of articles to thematic groups (or strategic approaches) relied on identifying the dominant directional relationship investigated, determining which dimension acted as the primary driver, which served as the outcome, and how the third dimension was framed (e.g., as a mediator, moderator, or context). Throughout the process, articles were continually revisited and compared, allowing us to assess how thematic elements converged or diverged across studies. Papers were examined not in isolation but in relation to one another, enabling the identification of concordant themes and their interrelations, thus ensuring internal consistency within themes and conceptual coherence between them.

To ensure rigor in the categorization process, specific criteria were applied to resolve instances of ambiguity. The final categorization was determined through a consensus-based process of re-evaluation, where the paper's core research question and theoretical contribution were weighted against its secondary findings. A critical example of this rigorous distinction involved separating thematic group 1 from the other clusters. Given that a majority of the selected studies utilized international samples, such as MNEs or global supply chains, there was a potential risk of not distinguishing the empirical setting from the theoretical focus. This issue was resolved by determining whether internationalization functioned as a passive context or an active force. For instance, studies that examined how digital tools improve sustainability performance, while using MNEs merely as a data source without theorizing how being international altered the relationship, were assigned to group 1, which considers internationalization as a context. In contrast, papers were assigned to subsequent groups only

when they demonstrated that the specific dynamics of global expansion actively strengthened, weakened, or drove the digital-sustainability interplay.

This analytical procedure provided the foundation for classifying the literature into strategic thematic groups, developing a conceptual framework that synthesizes the current state of research, and identifying future research avenues, highlighting areas that require deeper exploration.

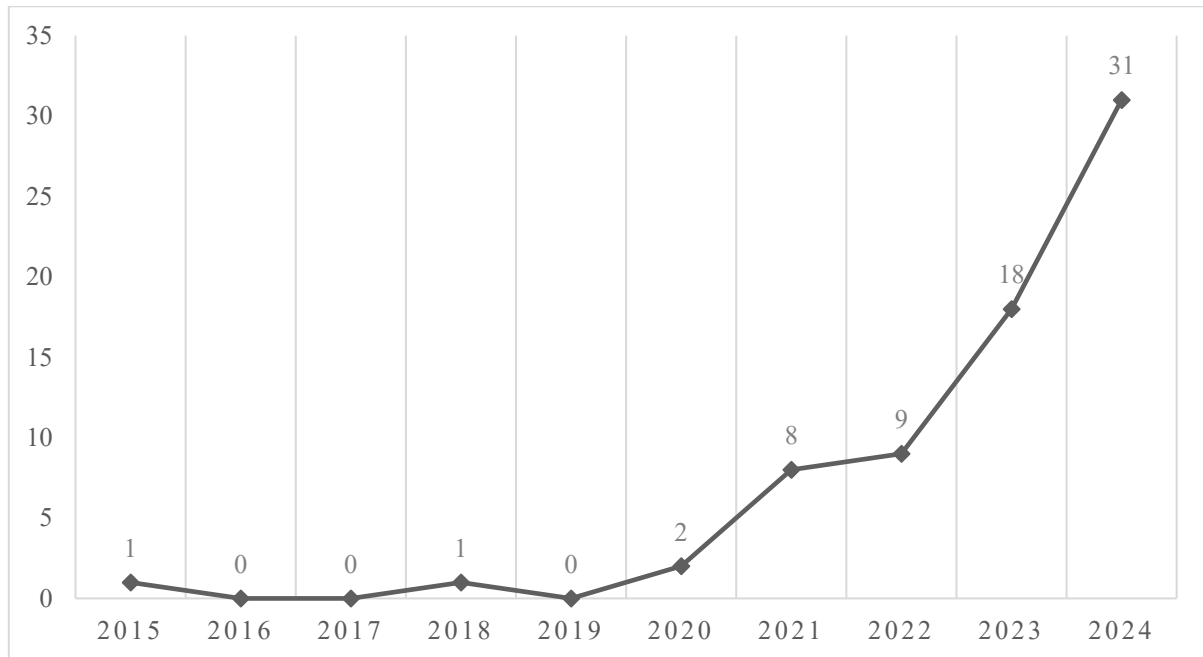
3. Descriptive findings

By analyzing the selected papers, we identified key patterns and trends that shed light on the evolution of this multidisciplinary research field. Following the approach of previous literature reviews (Romanello and Chiarvesio 2019; Ocelik et al. 2023; Baltazar et al. 2025) we conducted a descriptive analysis to trace the trajectory of scholarly interest and to contextualize the growing integration of digital transformation, sustainability, and internationalization.

The temporal distribution of papers reveals a progressive increase in academic engagement with this intersection (see Figure 2.2). The first contribution emerged in 2015. Over the years, there has been a steady increase in the number of publications. Notably, there is a significant surge from 2021 onward, with 66 articles. This sharp rise shows a heightened focus on these themes and emphasizes their importance in current academic discussion.

Most of the selected papers were published in the *Journal of Cleaner Production*, a sectoral journal addressing various topics within the environmental and digital domains. The second most common publication source was *Technological Forecasting and Social Change*. Finally, a few contributions also appeared in broader management journals, such as the *Review of Managerial Science*, *Academy of Management Perspectives*, and *Journal of Business Research*. The distribution of selected papers across journal sources, categorized by year of publication, is summarized in Table 2.1.

Figure 2.2. Year distribution of the publications



Based on the field categorization outlined in the ABS ranking (CABS 2021), the selected articles span a wide range of research domains (see Table 2.2). The majority were published in ethics, corporate social responsibility, and management journals (13), followed by international business and area studies (11), and innovation journals (10). Additional contributions come from outlooks in sectoral studies (8), operations and technology (7), economics (6), finance (4), social sciences (4), information management (2), organizational studies (1), accounting (1), marketing (1), entrepreneurship and small business management (1), and human resource management (1). This broad disciplinary spread reflects the interdisciplinary nature of research exploring the intersection of digital transformation, sustainability, and internationalization.

Table 2.2. Number of papers by field of research (CABS 2021)

Field	N. of Articles
ACCOUNT	1
ECON	6
ENT-SBM	1
ETHICS-CSR-MAN	13
FINANCE	4
HRM&EMP	1
IB&AREA	11
INFO MAN	2
INNOV	10
MKT	1
OPS&TECH	7
ORG STUD	1
SECTOR	8
SOC SCI	4

Most of the reviewed papers are empirical in nature (51). However, the sample includes theoretical works (10) and literature reviews (9) that explore the topic from various conceptual and methodological angles. Among the 51 empirical studies, 26 employed quantitative methods, 20 used qualitative approaches, and 5 adopted mixed-methods designs.

The geographical focus of empirical works reveals two primary analytical categories: single-country studies (31) and cross-country analyses (20). Among single-country studies, the strongest focus is on Asia (20), followed by the Americas (5) and Europe (5). Only one study examined Africa. In contrast, cross-country analyses reflect a global perspective with insights from multiple nations and regions. Notably, 5 empirical papers adopted a truly global approach to exploring digitalization, sustainability, and internationalization. The geographical breakdown is detailed in Table 2.3.

Table 2.1. Distribution of articles by journal source by year

Journal Title	Total	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Academy of Management Perspectives	1							1			
Africa Journal of Management	1								1		
Applied Economics	1										1
British Journal of Management	1				1						
BRQ Business Research Quarterly	1							1			
Business Horizons	1										1
Business Strategy and the Environment	3						1				2
Cogent Business and Management	1										1
Competitiveness Review	1										1
Corporate Governance (Bingley)	1							1			
Energy Economics	2										2
European Journal of Industrial Relations	1						1				
European Management Journal	1									1	
Finance Research Letters	2										2
Global Finance Journal	1										1
IEEE Transactions on Engineering Management	1									1	
Industrial Marketing Management	1									1	
Industry and Innovation	1								1		
Information Society	1										1
International Journal of Business Governance and Ethics	1										1
International Journal of Logistics Research and Applications	1										1
International Journal of Operations and Production Management	1										1
Journal of Business Research	2							1	1		
Journal of Cleaner Production	8							3	1	3	1
Journal of Global Information Management	1									1	
Journal of Humanitarian Logistics and Supply Chain Management	1	1									
Journal of Industrial and Business Economics	1									1	
Journal of International Business Studies	3									1	2
Journal of International Entrepreneurship	1										1

Table 2.1. (Continue)

Journal of International Management	2											2
Journal of Manufacturing Technology Management	1									1		
Journal of Product Innovation Management	1									1		
Journal of Technology Transfer	1											1
Journal of World Business	2							1		1		
Management Decision	1									1		
Managerial and Decision Economics	1											1
Operations Management Research	1									1		
Organization and Environment	1									1		
Review of International Economics	1											1
Review of International Political Economy	1							1				
Review of Managerial Science	1									1		
Scandinavian Journal of Management	1											1
Sustainability Accounting, Management and Policy Journal	1											1
Technological Forecasting and Social Change	6						1		2			3
Technovation	1									1		
Thunderbird International Business Review	2											2
TQM Journal	1									1		
Transnational Corporations Review	1								1			
Total	70	1	0	0	1	0	2	8	9	18	31	

Table 2.3. Geographical scope of empirical articles

Study Type	Country/Region
Single-country study (31)	Asia (20) - <i>Bangladesh</i> (Dwivedi et al., 2022; Ringvold et al., 2023) - <i>China</i> (Brueck, 2024; Guo et al., 2024; Il Park & Xiao, 2021; Khurram et al., 2024; Li et al., 2023; Li & Sun, 2024; Liu et al., 2024; Ma et al., 2024; Wang et al., 2024; Xiao et al., 2024; Zhang et al., 2024; Zhang & Deborah, 2024) - <i>India</i> (Ajwani-Ramchandani et al., 2021; Jamwal et al., 2023; Sharma et al., 2024) - <i>Pakistan</i> (Mustafa et al., 2024) - <i>Taiwan</i> (Chien et al., 2022) - <i>Vietnam</i> (Pham and Vu, 2024) America (5) - <i>Brazil</i> (Oliva et al., 2022) - <i>Mexico</i> (Larios-Hernandez, 2024) - <i>USA</i> (Asi et al., 2023; Le and Vu, 2024; McDonald, 2024) Europe (5) - <i>Germany</i> (Holl and Mariotti, 2022) - <i>Italy</i> (Denicolai et al., 2021) - <i>Portugal</i> (Ratten and Braga, 2024) - <i>Spain</i> (Díaz-Chao et al., 2021) - <i>Sweden</i> (Oghazi et al., 2024) Africa (1) - <i>Kenya</i> (Tatham et al., 2015)
Cross-country study (20)	- <i>USA, Denmark, Sweden, Norway, Finland, Belgium, Netherlands, Ireland, Taiwan, Singapore, China, Australia, Chile</i> (Patchell and Hayter, 2021) - <i>Australia, Canada, Denmark, France, Germany, Greece, Italy, Norway, Portugal, Spain, Switzerland, UK, USA</i> (Forcadell et al., 2020) - <i>Australia, Europe</i> (Choy et al., 2023) - <i>Brazil, India, Tanzania, Ethiopia, Colombia, Uganda, Haiti, Dominican Republic, El Salvador, Guatemala, Peru, Indonesia, Vietnam</i> (Cortese et al., 2024) - <i>Europe</i> (Del Giudice et al., 2021; Fayyaz et al., 2024; Ferreira et al., 2023; Johnstone, 2024; López-Nicolás et al., 2024) - <i>Europe, Brazil, Canada, UK, USA</i> (Suchek et al., 2024) - <i>Germany, Norway, UK</i> (Stroud, 2020) - <i>Nigeria, Uganda, Zambia</i> (Oyinlola et al., 2022) - <i>Scandinavia</i> (Chaudhuri et al., 2024) - <i>Europe, North America</i> (Kolagar, 2024) - <i>UK, New Zealand</i> (Akhtar et al., 2018) - <i>Global</i> (Falcke et al., 2024; Li et al., 2023; Valero-Gil et al., 2024; Wang and Ramsey, 2024; Wang et al., 2024)

4. Thematic Analysis

4.1. Evolving perspectives: Previous literature reviews

An analysis of existing literature reviews reveals that research on the interplay between digital transformation, sustainability, and internationalization has predominantly focused on specific intersections, technologies, or sectoral perspectives. Some studies adopt a GVC lens, examining how Industry 4.0 and additive manufacturing enable circular economy practices, decentralized production, and more resilient supply chains (Awan et al. 2022; Giacosa et al. 2024). Others emphasize the broader societal and environmental implications of advanced digital

technologies (i.e., AI and big data), particularly in response to systemic disruptions such as the COVID-19 pandemic (Sajjad 2021; Dauvergne 2022; Galetsi et al. 2024). Additional reviews investigate how sustainability goals are being pursued in international contexts, focusing on digital innovation within MNEs (Sanili Aydin and Uste 2022; Dias Lopes et al. 2023; Ocelik et al. 2023) or on how AI can support specific SDGs in global markets (Hasan and Ojala 2024).

Collectively, these reviews engage with the three focal topics addressing digital transformation, sustainability, and international business perspectives. Nonetheless, their contributions are often structured around specific analytical lenses, such as particular technologies, governance structures, or external disruptions. As a result, most offer valuable but focused insights rather than exploring the mutual interdependence of all three domains. Furthermore, aspects such as firm-level integration, strategic alignment, and the role of institutional context are often addressed from a narrow perspective. This indicates an opportunity to complement existing work with a more integrative view that considers how firms simultaneously navigate and align these complex transitions.

4.2. Analysis of conceptual and empirical papers: a synthetic framework

We categorized the selected literature into five mutually exclusive thematic groups, assigning each study to a single category (see Figure 2.3).

Within each thematic group, the analysis delves into the specific dynamics that shape relationships among digital transformation, sustainability, and internationalization. These dynamics are illustrated through synthesized conceptual models. Although rooted in the findings of the analyzed papers, these frameworks constitute an original interpretation developed to reduce theoretical fragmentation and visualize relationships that were often implicit. Building upon conceptual frameworks and empirical evidence, our thematic analysis

offers a comprehensive understanding of the field by uncovering the key issues investigated and their interconnections (see Table 2.4).

Figure 2.3. Thematic grouping of conceptual and empirical studies

Thematic Group	Framework of Analysis	Conceptual Papers	Empirical Papers
1. Digitalization's role in shaping sustainability in IB	INTERNATIONAL BUSINESS CONTEXT DIGITALIZATION → + → SUSTAINABILITY	4	19
	INTERNATIONAL BUSINESS CONTEXT DIGITALIZATION → - → SUSTAINABILITY	2	
	INTERNATIONAL BUSINESS CONTEXT CHALLENGES OF DIGITALIZATION FOR SUSTAINABILITY		2
2. Digitalization driving sustainability and the influence of internationalization	INTERNATIONALIZATION ↓ DIGITALIZATION → SUSTAINABILITY		3
	INTERNATIONALIZATION ↙ ↘ DIGITALIZATION → SUSTAINABILITY		2
	SUSTAINABILITY ↓ DIGITALIZATION → INTERNATIONALIZATION		1
3. Digitalization as a catalyst for internationalization and the effect of sustainability	SUSTAINABILITY ↙ ↘ DIGITALIZATION → INTERNATIONALIZATION		3
	SUSTAINABLE BUSINESS DIGITALIZATION → INTERNATIONALIZATION		1
	SUSTAINABILITY DIGITALIZATION } → INTERNATIONALIZATION		3
	GRAND CHALLENGES Digitalization & Sustainability → INTERNATIONALIZATION	4	1
	DIGITALIZATION ↓ INTERNATIONALIZATION → SUSTAINABILITY		3
4. Internationalization driving the integration of digitalization and sustainability	DIGITALIZATION ↙ ↘ INTERNATIONALIZATION → SUSTAINABILITY		3
	SUSTAINABILITY ↙ ↘ INTERNATIONALIZATION → DIGITALIZATION		1
	INTERNATIONALIZATION → DIGITALIZATION – SUSTAINABILITY CONVERGENCE		3
	DIGITALIZATION ↙ ↘ SUSTAINABILITY → INTERNATIONALIZATION		1
	DIGITAL BUSINESSES INTERNATIONALIZATION PROCESSES & SUSTAINABILITY		4
5. Sustainability's influence on internationalization and digital transformation	SUSTAINABILITY → INTERNATIONALIZATION DIGITALIZATION		1

4.2.1. Thematic Group 1: Digitalization's role in shaping sustainability in IB

Among the five thematic domains, the most substantial body of work (27 studies) centers on the role of digitalization as a catalyst for sustainability within IB. These contributions tend to focus primarily on digitalization and sustainability, while internationalization often serves as a contextual backdrop rather than a dynamic analytical component. This thematic cluster can be synthesized around three interconnected analytical pillars – enabling mechanisms, paradoxes and tensions, and structural and contextual challenges.

The first and most dominant pillar frames digitalization as a strategic enabler of sustainability. Across conceptual contributions, digital tools are presented as central to embedding environmental, sustainability, and governance (ESG) goals within international operations. Wang et al. (2024) highlight digital governance mechanisms in GVC, while other studies extend this view, showing how digital platforms and specific technologies help address social and environmental goals, particularly in underserved global markets (Yi et al. 2023; Ciulli and Kolk 2023; Verbeke et al. 2024). Empirical research reinforces this enabling role. Ferreira et al. (2023) and Liu et al. (2024) show that Industry 4.0 adoption improves ESG performance, while Zhang et al. (2024) link digital transformation to greener export production. The role of digitalization in advancing circular economy models is also prominent, including through digitally enabled business models (Oghazi et al. 2024), data-driven strategies (Johnstone 2024), and digital solutions for waste and resource challenges in emerging markets (Ajwani-Ramchandani et al. 2021; Oyinlola et al. 2022; Chaudhuri et al. 2024). Beyond technical effects, digitalization facilitates stakeholder empowerment and ecosystem coordination (Cortese et al., 2024; Kolagar, 2024; Li et al., 2023), expanding the social architecture of sustainability. Digital technologies are also revolutionizing GVC management by enhancing transparency and addressing ethical challenges. Smart disclosure by MNEs can reduce supplier human rights violations (Wang et al., 2024), while digital technological

advances can increase environmental pressures on foreign firms, promoting greener practices (Wang & Ramsey, 2024). Sectoral applications, from energy efficiency (Stroud 2020) to humanitarian logistics (Tatham et al. 2015) and sustainable manufacturing (Chien et al. 2022), demonstrate digitalization's operational versatility. However, its effectiveness depends on firm-level capabilities (Mustafa et al., 2024) and is increasingly integrated into broader strategic transformations involving diplomacy and customer-facing innovation (Asi et al., 2023; McDonald, 2024).

While the prevailing narrative emphasizes digitalization's promise, the second pillar highlights its ambivalence. A critical subset of studies addresses the unintended consequences of digital globalization. Verbeke & Hutzschenreuter (2021) warn of exclusion, data abuse, and monopolization, while Malik and Froese (2022) show how digital tools can facilitate corruption in weak institutional environments. These works caution against techno-optimism and call for stronger governance to align digitalization with sustainability objectives across borders.

The third pillar addresses the structural barriers that limit the realization of digital-sustainability strategies, especially in developing and emerging markets. Capability gaps, resource shortages, and institutional fragmentation hinder the integration of Industry 4.0 technologies into sustainability agendas (Dwivedi et al. 2022; Jamwal et al. 2023). These studies highlight internationalization as a critical contextual dimension that influences the scope, direction, and effectiveness of digital innovation in advancing sustainability objectives.

4.2.1. Thematic Group 2: Digitalization driving sustainability and the role of internationalization

A second group of papers (5) examines internationalization as a strategic factor influencing how digitalization drives sustainability in firms. Two distinct internationalization roles emerge

– moderator and mediator – each shaping the digitalization-sustainability link through different mechanisms.

In the first perspective, internationalization conditions the impact of digitalization on sustainability. It shapes how effectively digital tools, such as big data, translate into environmental or ESG outcomes. Le and Vu (2024) find that digitalization improves environmental performance, and this relationship strengthens in firms with international operations. Similarly, Xiao et al. (2024) show that digital technologies support ESG practices by enhancing resource flexibility and stakeholder engagement, with internationalization further reinforcing this effect. However, this interplay is not always synergistic. Suchek et al. (2024) report that, in SMEs, the simultaneous adoption of Industry 4.0 technologies and integration into GVCs can create tensions, particularly in circular economy initiatives. While each factor promotes sustainability, their combination may introduce strategic complexities.

In a second stream, internationalization acts as a channel through which digitalization leads to sustainability. It facilitates this transition by activating capabilities, networks, and values aligned with sustainable goals. Del Giudice et al. (2023) show that automation supports human rights objectives when mediated by social entrepreneurship international new ventures (INVs). Likewise, Akhtar et al. (2018) find that international business networks mediate the link between managerial digital competencies and environmental sustainability, emphasizing the role of relational mechanisms in transferring digital capabilities into impact.

Table 2.4. Core focus and mechanisms identified in the thematic analysis of conceptual and empirical studies

Thematic Group	Core Focus	Mechanisms	Role of Digitalization	Role of Sustainability	Role of Internationalization	References
1. <i>Digitalization's role in shaping sustainability in IB</i>	Digitalization as a catalyst for sustainability in IB	- Enabling mechanism of digitalization - Paradoxes and tensions between digitalization and sustainability - Structural and contextual challenges in IB	<i>Driver:</i> Serves as a catalyst and enabler or hinderer of sustainability	<i>Outcome:</i> The result of the process, driven by digitalization	<i>Context:</i> Serves as a contextual backdrop for the digitalization–sustainability nexus	Ajwani-Ramchandani et al. (2021); Asi et al. (2023); Chaudhuri et al. (2024); Chien et al. (2022); Ciulli & Kolk (2023); Cortese et al. (2024); Ferreira et al. (2023); Johnstone (2024); Kolagar (2024); Li et al. (2023); Liu et al. (2024); McDonald (2024); Mustafa et al. (2024); Oghazi et al. (2024); Oyinlola et al. (2022); Stroud (2020); Tatham et al. (2015); Verbeke et al. (2024); Wang & Ramsey (2024); Wang (2023); Wang et al. (2024); Yi et al. (2023); Zhang et al. (2024) Malik & Froese (2022); Verbeke & Hutzschenreuter (2021) Dwivedi et al. (2022); Jamwal et al. (2023)
2. <i>Digitalization driving sustainability and the role of internationalization</i>	The influence of internationalization on the digitalization-sustainability nexus	- Moderating effect of internationalization - Mediating effect of internationalization	<i>Driver:</i> Serves as the initial catalyst for sustainability outcomes	<i>Outcome:</i> The result that is either strengthened or channeled through internationalization	<i>Moderator:</i> Strengthens the digitalization-sustainability link <i>Mediator:</i> Acts as a channel, activating networks/capabilities	Le & Vu (2024); Suchek et al. (2024); Xiao et al. (2024) Akhtar et al. (2018); Del Giudice et al. (2023)

Table 2.4. (Continued)

3.	<i>Digitalization as a catalyst for internationalization and the effect of sustainability</i>	The influence of sustainability on the relationship between digitalization and internationalization	• Moderating effect of sustainability • Mediating effect of sustainability • Sustainability as a contextual force • Sustainability as a co-driver • Sustainability as a Grand Challenge	<i>Driver:</i> Serves as the initial catalyst for internationalization	<i>Moderator:</i> Creates resource conflicts <i>Mediator:</i> Enables digital innovations <i>Contextual factor:</i> Shapes firm strategies <i>Co-driver:</i> Works synergistically with digitalization <i>Grand Challenge:</i> Forces firms to rethink their international strategies	<i>Outcome:</i> The result that is either influenced or driven by digitalization and sustainability	Denicolai et al. (2021) Guo et al. (2024); Pham & Vu (2024); Ratten & Braga (2024) Fayyaz et al. (2024) Díaz-Chao et al. (2021); Forcadell et al. (2020); Li & Sun (2024) Asakawa & Clegg (2024); Choy et al. (2023); Etemad (2023); George & Schillebeeckx (2022); Pla-Barber et al. (2021)
4.	<i>Internationalization driving the integration of digitalization and sustainability</i>	The influence of internationalization on the integration of digitalization and sustainability	• Moderating effect of digitalization • Mediating effect of digitalization • Mediating effect of sustainability • Strategic convergence of digitalization and sustainability outcomes	<i>Moderator:</i> Enhances the firm's ability to transfer and scale green practices <i>Mediator:</i> Serves as a channel through which internationalization leads to sustainability <i>Outcome:</i> Stimulated by internationalization	<i>Outcome:</i> The outcome of the process <i>Mediator:</i> The channel through which internationalization stimulates digital upgrading	<i>Driver:</i> The active catalyst that triggers internal transformation toward digitalization and sustainability	Li et al. (2023); Park & Xiao (2021); Wang et al. (2024) Falcke et al. (2024); Sharma et al. (2024); Zhang & Deborah (2024) Khurram et al. (2024) Brueck (2024); Holl & Mariotti (2022); Valero-Gil et al. (2024)
5.	<i>Sustainability's influence on internationalization and digital transformation</i>	How sustainability acts as a strategic catalyst for internationalization particularly when combined with digitalization	• Mediating effect of digitalization • Digitalization as a contextual force • Co-evolution of internationalization and digitalization	<i>Mediator:</i> Mediates the link between sustainability and internationalization <i>Context:</i> The core context in which sustainability drives internationalization <i>Co-evolutionary outcome:</i> The outcome of sustainability practices	<i>Driver:</i> The active catalyst for internationalization and digital transformation	<i>Outcome:</i> The end result of the process driven by sustainability initiatives	Ma et al. (2024) Larios-Hernandez (2024); Oliva et al. (2022); Patchell & Hayter (2021); Ringvold et al. (2023) López-Nicolás et al. (2024)

4.2.3. Thematic Group 3: Digitalization as a catalyst for internationalization and the effect of sustainability

Another substantial group of works (13) examines how digitalization drives internationalization, and how sustainability shapes this process through five distinct yet overlapping mechanisms – as a moderator, a mediator, a strategic co-driver, and a contextual force shaping how firms act in global markets, and a fundamental global challenge impacting IB.

First, sustainability has been considered as a moderator of the relationship between digitalization and international performance. Denicolai et al. (2021) show that while AI readiness significantly boosts SMEs' international performance, simultaneously pursuing sustainability and digitalization can create resource conflicts, turning what might be complementary growth paths into competing priorities, especially for resource-constrained firms.

Second, sustainability often plays a mediating role by enabling specific digital innovations to effectively accelerate internationalization. Research by Pham and Vu (2024) and Guo et al. (2024) reveals how sustainable business models and ESG responsibilities positively mediate the impact of digital tools, such as digital forensic accounting and Industry 4.0 technologies, helping firms overcome barriers and rapidly expand into new markets. Similarly, Ratten & Braga (2024) show that for Portuguese women entrepreneurs, digital empowerment combined with co-creation and sustainability initiatives significantly facilitates their internationalization success.

Third, sustainability can act as a contextual factor. Fayyaz et al. (2024) find that digital competences in sustainability-oriented firms can enhance their capacity for cross-border expansion, which in turn positively affects overall firm outcomes.

Fourth, literature positions sustainability as a strategic co-driver of internationalization, often through its synergistic integration with digitalization, advanced technologies, and institutional support. Forcadell et al. (2020) demonstrate that a reputation for corporate sustainability can enhance the international impact of digital transformation by fostering trust and customer loyalty. Díaz-Chao et al. (2021) show that environmental assets, when combined with Industry 4.0 technologies, significantly boost exports, productivity, and innovation outcomes. Similarly, Li & Sun (2024) find that government subsidies promote outward foreign direct investments (OFDI) by improving firms' ESG performance, which enhances legitimacy, competitiveness, and alignment with global stakeholder expectations.

Finally, research contextualizes digitalization and sustainability as two major global challenges, compelling MNEs and SMEs alike to reframe their corporate purpose and strategies amidst geopolitical market pressures (George and Schillebeeckx 2022; Etemad 2023). Digital technologies and calls for sustainability have accelerated regionalization trends in GVCs, offering new opportunities for reshoring (Pla-Barber et al. 2021), reshaping firms' location strategies in global cities (Asakawa and Clegg, 2024), and driving cross-border collaborations (Choy et al. 2023).

4.2.4. Thematic Group 4: Internationalization driving the integration of digitalization and sustainability

A fourth thematic group (10) reframes internationalization as an active driver for both digitalization and sustainability. This perspective highlights how international expansion can trigger internal transformation. While in some instances, digitalization and sustainability act as distinct mediating or moderating forces, the overarching dynamic suggests that the complexity of global markets increasingly pushes firms toward integrating these domains.

First, internationalization can drive sustainability outcomes, with digitalization being a moderator that enhances firms' ability to transfer, scale, and harmonize green practices across borders. For instance, adopting OFDI can enhance green innovation performance, particularly when supported by digital transformation strategies that enable MNEs to effectively transfer green practices across borders (Wang et al., 2024). Similarly, the diversity of environmental practices across regulatory contexts can complicate green innovation efforts in MNEs, but digitalization can mitigate these challenges by harmonizing practices and fostering knowledge exchange within global networks (Li et al., 2023). Additionally, high digitalization capabilities in foreign subsidiaries can enhance their capacity to respond to institutional pressures, such as anti-corruption measures, strengthening their reputation and innovation potential (Park and Xiao 2021).

Other contributions position digitalization as a mediator of the internationalization-sustainability nexus. Firms addressing climate change through internationalization increasingly rely on digitally enabled innovation ecosystems, including incumbent-led digital platforms and co-creation with customers and complementors to support sustainable practices (Falcke et al. 2024). Digitalization enhances the sustainability impact of internationalization by improving access to finance, strengthening legitimacy, and reducing risks, highlighting the strategic value of integrating digital and global expansion effects (Zhang & Deborah, 2024). Furthermore, Industry 4.0 technologies play a critical role in decarbonizing GVCs, particularly under the influence of international regulatory and market pressures (Sharma et al. 2024).

Conversely, sustainability can represent a mediator that shapes how internationalization stimulates digital upgrading, particularly when strong ESG performance aligns global expansion with long-term digital transformation goals (Khurram et al. 2024).

Finally, research demonstrates how internationalization drives the simultaneous adoption of digital and sustainable practices, making a shift toward strategic convergence. In

this configuration, internationalization acts as a binding force. The complexities and resource requirements of global expansion require a unified strategic response, where digital and environmental capabilities are co-developed rather than treated in isolation. SMEs are particularly well-positioned for this dual transformation, as firms pursuing growth, innovation, and export-oriented goals in favorable environments are more likely to achieve digital-sustainability convergence (Valero-Gil et al. 2024). Foreign MNEs are also central players. For instance, Brueck (2024) investigates the role of foreign MNEs in China's twin transition, finding that AI applications for green transition are primarily developed in cross-company projects led by local authorities through industrial districts. Moreover, research shows how engagement in international markets positively relates to digital and environmental logistics innovation (Holl & Mariotti, 2022). This indicates that internationalization creates the necessary conditions for strategies that facilitate the simultaneous adoption of the two paths.

4.2.5. Thematic Group 5: Sustainability's influence on internationalization and digital transformation

A fifth thematic group (6) explores how sustainability serves as a strategic catalyst for internationalization, particularly when combined with digitalization. Though diverse in focus, these studies converge in highlighting how sustainability initiatives can either drive or shape global expansion, often through digitally enabled processes and in digital business contexts. Some works examine how sustainability drives internationalization, with digitalization mediating this relationship. Green finance, for instance, can drive technological innovation and improve firms' compliance and innovation capabilities, thereby enhancing export performance (Ma et al. 2024).

Similarly, in digital-born businesses, sustainability and digitalization are deeply intertwined. Models such as Alibaba's digital villages in Mexico (Larios-Hernandez 2024) and

renewable energy strategies in tech firms (Patchell and Hayter 2021) show how green digital capabilities enable international expansion. These firms develop green firm-specific advantages, aligning digital strategy with sustainability to pursue global competitiveness. For born global startups in Industry 4.0, sustainability appears as both a growth driver and a constraint of international expansion, contingent on capabilities and resource availability (Oliva et al. 2022). In mature firms, developing sustainability-oriented business models requires strong organizational capacity, enabling innovation and alignment with global markets (Ringvold et al. 2023).

Finally, sustainability also influences how internationalization and digitalization co-evolve, as in the case of family firms, where corporate social responsibility shapes innovation and international strategy, reinforcing the integration of digital and sustainability objectives (López-Nicolás et al. 2024).

5. What comes next? Discussion and future research agenda

Our thematic analysis of the literature revealed five distinct yet interrelated configurations through which digital transformation, sustainability, and internationalization interact at the firm level. The review uncovered both more explored areas and conceptual blind spots, often related to under-theorized mechanisms, underexplained contextual variance, or partial methodological depth. Drawing upon these thematic insights, we outline five future research avenues along with a set of integrative directions to guide future works in this emerging field (see Table 2.5).

The first thematic cluster identified digitalization as a strategic enabler of sustainability in IB. Numerous studies highlight how digital tools contribute to ESG performance, enable circular economy models, and support sustainable value chains in global markets (Ferreira et al. 2023; Liu et al. 2024; Oghazi et al. 2024). However, while the positive impacts of digitalization are well documented, significantly less attention has been devoted to its long-

term consequences, including rebound effects, energy intensification, or digital inequality. For example, Verbeke and Hutzschenreuter (2021) and Malik and Froese (2022) raise important concerns about the unintended consequences of digital globalization, such as exclusion, corruption, or surveillance. The literature also offers limited insight into how firms govern the trade-offs between digital efficiency and sustainability across diverse institutional contexts. Governance mechanisms, particularly in GVCs, remain under-specified despite their centrality in aligning digital initiatives with sustainability objectives (Wang et al., 2024; Wang, 2023). Thus, there is a pressing need to understand how digitalization and sustainability strategies evolve over time and under what governance conditions they deliver lasting environmental and social value. Hence, we propose:

Future research avenue 1: Examining the long-term consequences and governance of digital transformation and sustainability strategies in international contexts.

In the second thematic group, internationalization emerged not merely as a context but as a moderating or mediating force that shapes how digitalization contributes to sustainability. Scholars such as Le and Vu (2024), Suchek et al. (2024) and Xiao et al. (2024) explore how international market pressures and global partnerships strengthen the digital-sustainability link, especially through access to new resources, standards, and stakeholder demands. However, the literature does not sufficiently differentiate between types of internationalization – such as export-led growth, joint ventures, or platform-based entry – and how these pathways shape the success or failure of digital-sustainability integration. Akhtar et al. (2018) and Del Giudice et al. (2023) show that international networks can mediate the impact of digital capabilities on sustainability, but such mechanisms are only beginning to be theorized. Moreover, in emerging markets, where technological and regulatory infrastructures are often weak, the role of internationalization in the digital-sustainability link remains poorly understood. In this context, we propose:

Future research avenue 2: Unpacking how different internationalization configurations condition the success of digital transformation initiatives to achieve sustainability outcomes.

Table 2.5. Suggested avenues for future research

Thematic Group	Future Research Avenue	Research Questions
1. <i>Digitalization's role in shaping sustainability in IB</i>	Examining the long-term consequences and governance of digital transformation and sustainability strategies in international contexts.	- What are the long-term environmental and social effects of digital transformation initiatives in international firms? - How do firms govern trade-offs between digital efficiency and sustainability in GVCs? - How do institutional contexts influence the evolution of digital-sustainability strategies over time?
2. <i>Digitalization driving sustainability and the influence of internationalization</i>	Unpacking how different internationalization configurations condition the success of digital transformation initiatives to achieve sustainability outcomes.	- How do different modes of internationalization affect digital-sustainability integration? - What role do international networks play in transferring digital capabilities into sustainability outcomes? - How do the levels of international exposure moderate the impact of digital tools on ESG performance?
3. <i>Digitalization as a catalyst for internationalization and the effect of sustainability</i>	Investigating how digital and sustainability-oriented capabilities shape the pathways and pace of international expansion	- Which digital capabilities most effectively support sustainable international expansion? - How do sustainability practices enhance or constrain the scalability of digital tools for international outcomes? - What role do sectoral characteristics play in shaping the effectiveness of digital sustainability strategies for international success?
4. <i>Internationalization driving the integration of digitalization and sustainability</i>	Analyzing how international expansion triggers internal configurations of digital and sustainable strategies within firms	- How do firms internally realign governance and processes to support digital-sustainability convergence during international expansion? - What organizational factors enable or hinder digitalization and sustainability outcomes in MNEs and SMEs? - How do foreign market ESG expectations influence internal innovation and decision-making structures?
5. <i>Sustainability's influence on internationalization and digital transformation</i>	Examining how sustainability goals act as strategic drivers of digital transformation and international growth	- Under what conditions does sustainability become a primary driver of digitalization and internationalization? - How do firm values, leadership orientation, and external legitimacy shape sustainability-led growth strategies? - How do SMEs and digital-born firms leverage green practices for competitive international positioning?

The third thematic cluster emphasized the role of digitalization as a catalyst for internationalization, with sustainability affecting this relationship. Several studies demonstrate that digital tools enhance international competitiveness, especially for SMEs, and that sustainability practices can amplify or restrict this effect by either supporting legitimacy, innovation, and resilience (Pham and Vu 2024; Guo et al. 2024), or reducing resource availability at the firm level (Denicolai et al. 2021). Yet there remains a gap regarding what specific capabilities enable firms to effectively integrate digital and sustainable practices for international expansion. This includes not only technical competencies but also strategic and organizational capabilities – such as data governance, stakeholder engagement, or ESG alignment – that shape how firms pursue and sustain growth across borders. In addition, sectoral variations are rarely addressed, despite their potential influence on how sustainability-oriented digital transformation translates into global advantage. Thus, an opportunity emerges to investigate how firms build and leverage digital capabilities and green practices that are both scalable and context sensitive. Consequently, we propose:

Future research avenue 3: Investigating how digital and sustainability-oriented capabilities shape the pathways and pace of international expansion.

In the fourth thematic group, internationalization was not a contextual factor or outcome but rather a driver of internal transformation, prompting firms to align their digital and sustainability strategies. Empirical work suggests that participation in global markets can stimulate the adoption of digital tools and sustainable innovation (Brueck, 2024; Li et al., 2023; Wang et al., 2024). This process is particularly evident in export-oriented SMEs, where international growth, digital and sustainable innovations are closely linked (Holl and Mariotti 2022; Valero-Gil et al. 2024). Yet while we understand the outputs of such integration, less is known about how firms internally reconfigure their strategies, governance structures, and processes to support convergence. The literature has yet to capture how internationalization

reorients decision-making across organizational levels to simultaneously achieve digital upgrading and sustainability goals. There are also limited insights into how firms adapt their innovation systems, performance metrics, and leadership models in response to global environmental pressures. For this reason, we propose:

Future research avenue 4: Analyzing how international expansion triggers internal configurations of digital and sustainable strategies within firms.

Finally, the fifth thematic group, while less mature, offers a compelling shift in perspective by positioning sustainability as a strategic driver of both digital transformation and internationalization. Specifically, green practices and sustainability orientations are not constraints but enablers of international market outcomes (Patchell and Hayter 2021; Ma et al. 2024). These firms often adopt digital platforms and green technologies as tools to achieve their environmental commitments on a large scale. Nonetheless, literature provides limited generalization across sectors or regions, and there is a need to theorize under what conditions sustainability drives internationalization, while considering the role of digital transformation in the equation. Factors such as leadership orientation, legitimacy-seeking behaviors, stakeholder pressure, and access to green finance may all shape these dynamics, but have not been studied systematically. Thus, we propose:

Future research avenue 5: Examining how sustainability goals act as strategic drivers of digital transformation and international growth.

In addition, across all five thematic groups, several integrative research directions also emerge. First, the literature would benefit from the development of explanatory frameworks that capture the causal dynamics, synergies, and trade-offs that characterize the digitalization-sustainability-internationalization nexus. While literature has mapped these relationships descriptively, few works offer robust theoretical explanations for how firms can balance these competing goals or sequence initiatives over time (Ciulli and Kolk 2023; Ocelík et al. 2023).

Thus, frameworks that combine strategic management with institutional and configuration theory could contribute to the field. Second, future research could adopt methodological approaches that move beyond static analysis. Although the reviewed literature includes diverse methods, longitudinal studies, comparative case analyses, and multi-level modeling remain rare (Denicolai et al., 2021; Li et al., 2023; Pham and Vu, 2024). Addressing the temporal evolution of digitalization-sustainability-internationalization strategies, how they emerge, change, and sometimes fail, is essential to understanding their full implications, particularly in volatile international contexts. Third, the role of context must be systematically theorized and empirically captured. Cultural, institutional, and industry differences significantly shape how firms engage in digital sustainability initiatives abroad (Le & Vu, 2024; Liu et al., 2024; Wang & Ramsey, 2024), yet most studies offer limited insights into these contextual contingencies. Comparative studies, especially across developed and emerging markets, could reveal structural barriers and enabling conditions for digitalization, sustainability, and internationalization integration.

6. Conclusions

This SLR has addressed a critical gap in the existing body of literature by exploring the complex and interdependent relationship between digital transformation, sustainability, and internationalization at the firm level. Drawing on thematic and descriptive analysis of 70 high-quality journal articles, we identified five distinct thematic configurations that illustrate how firms strategically align digital technologies with sustainability imperatives and internationalization objectives. In doing so, the review responds to calls in the IB literature for more integrative frameworks that reflect the realities of firms navigating increasingly complex global environments (Ghauri et al. 2021; Luo and Zahra 2023). The research reveals that digital technologies, particularly those associated with Industry 4.0, are frequently positioned as

enablers of sustainable practices and international growth (Díaz-Chao et al. 2021; Denicolai et al. 2021; Khurram et al. 2024). However, the effectiveness of their impact depends on a range of contextual and firm-level factors, including strategic orientation, resource constraints, and institutional environments (Denicolai et al. 2021; Xiao et al. 2024; Suchek et al. 2024). Moreover, internationalization is shown to play a more dynamic role than previously assumed, acting not only as a context but also as a driver, mediator, or moderator in shaping digital-sustainability trajectories (Brueck, 2024; Valero-Gil et al., 2024; Wang et al., 2024). Sustainability itself also emerges as a catalyst for innovation and global competitiveness (Ma et al. 2024), particularly in firms that strategically embed ESG considerations into their digital and internationalization strategies. One of the key theoretical insights from this review is the absence of robust conceptual foundations guiding this emerging domain. Although some studies draw on institutional theory (Park and Xiao 2021), dynamic capabilities (Valero-Gil et al. 2024), and stakeholder theory (Cortese et al. 2024), there is still room to deepen and extend their application. The field remains largely under-theorized, with few studies proposing integrative models or identifying causal mechanisms that explain how digital, sustainable, and international imperatives co-evolve. Our findings thus show the need to engage more deeply with theory and to develop frameworks that reflect the configurational and dynamic nature of this triadic nexus.

6.1. Limitations

Despite its contributions, the study is subject to limitations. First, the scope of the work is limited to journal articles, potentially excluding novel research trends emerging from conference proceedings and book chapters. Second, the rigorous analysis approach (Page et al. 2021) may have inadvertently excluded relevant papers that did not strictly adhere to the predefined inclusion criteria. Finally, despite the structured analytical framework, the review

may not fully reflect the intricate ways in which digital transformation, sustainability, and internationalization interact, given the diversity of approaches and contexts across the selected studies.

6.2. Implications

The findings of the study offer significant implications for theory and practice. From a theoretical standpoint, this review advances scholarly understanding by systemically identifying the ways in which digitalization, sustainability, and internationalization interact, overlap, and condition one another. The identification of five strategic configurations offers a clear view of how firms navigate this complex intersection and lays the groundwork for more robust theorizing. Specifically, our findings suggest the potential for developing integrative frameworks that draw on institutional, configuration, and capability-based theories to better explain how firms align and sequence digital and sustainability initiatives within the constraints and opportunities of international contexts.

In practical terms, the review offers guidance for managers seeking to reconcile digital, sustainable, and international goals. The synthesis highlights the importance of viewing digital transformation, sustainability, and international growth as fundamental strategic tools of value creation. However, the review also reveals tensions and trade-offs that must be managed, especially in SMEs (Denicolai et al. 2021), where capabilities and resources may be limited. Managers should thus prioritize the development of digital and sustainability-oriented competences, while tailoring strategies to sectoral, institutional, and geographic contexts. Finally, the findings highlight the need for coherent and supportive regulatory environments that facilitate the joint pursuit of digitalization and sustainability in IB. Attention should be paid to the specific needs of SMEs and firms in emerging markets, which often face greater barriers in integrating digital and sustainable strategies. Incentives and policies aimed at capacity-

building, green financing, and cross-border collaboration could play a pivotal role in accelerating the twin transitions in these contexts.

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Essay 2

INTEGRATING DIGITAL AND SUSTAINABLE STRATEGIES: CONTINGENT PATHWAYS TO INTERNATIONAL COMPETITIVENESS IN SMES

Abstract

In an increasingly competitive global market, digital transformation and sustainability have become essential drivers of international growth of small- and medium-sized enterprises (SMEs). Yet, research has not fully addressed how these two forces can impact SMEs' international competitiveness. This study examines nine Italian manufacturing SMEs and identifies four strategic pathways they adopt to address digital transformation and sustainability strategies: digital transformation-led, sustainability-led, parallel, and integrated approaches. Using a contingency theory perspective, the study shows that the success of each pathway depends on specific industry characteristics, market expectations, and internal resources. Firms that integrate digital and sustainability initiatives tend to achieve greater resilience and stronger international positioning, while those prioritizing a single strategy effectively meet specific regulatory or operational goals. The study makes contributions to both theory and practice in international business (IB) research on strategic integration, emphasizing the importance of context-sensitive strategies for achieving international success.

Keywords: Digital transformation, Industry 4.0, sustainability, international competitiveness, SDGs

1. Introduction

In the contemporary global economy, digitalization and sustainability have emerged as interconnected pillars of business strategy (Broccardo et al., 2023; Del Río Castro et al., 2021). Digital transformation is now central for firms competing in global markets (Ciulli and Kolk, 2023). Its transformative potential has reshaped industries and business operations (Dalenogare et al., 2018; Díaz-Chao et al., 2021), becoming a new frontier for international business (IB) research (Ahi et al., 2022; Luo and Zahra, 2023). Concurrently, sustainability has come to be an international priority for policy and businesses to protect planetary resources (Dantas et al., 2021; Griggs, 2013). The combination of digitalization and sustainability is crucial for

achieving international competitiveness, enabling firms to develop and maintain a profitable presence in the global marketplace (Denicolai et al., 2021; Oghazi et al., 2024).

Recent studies have examined the role of digital technologies in driving organizational change, innovation, and global expansion (Brieger et al., 2022; Hervé et al., 2020), while sustainability research has increasingly focused on corporate environmental responsibility, green innovation, and sustainable value creation as tools both limiting and allowing international success (Atz et al., 2023; Lopez-Torres et al., 2022; Rahi et al., 2022). However, despite the growing body of research (Ciulli and Kolk, 2023; Dias Lopes et al., 2023; Ferreira et al., 2023), the relationship between these two aspects and their implications for international competitiveness remain largely understudied (Dias Lopes et al., 2023; Ocelík et al., 2023). Moreover, existing research has primarily concentrated on large multinational enterprises (MNEs), providing limited insights into the challenges and opportunities faced by small- and medium-sized enterprises (SMEs) (George and Schillebeeckx, 2022; Ocelík et al., 2023). In particular, IB studies have tended to emphasize firms at the entry or early stages of internationalization (Brieger et al., 2022), overlooking the strategic dynamics of established international firms, which already possess a stable presence in foreign markets but must continuously adapt to maintain their international competitiveness (Suh and Kim, 2014). Numerous calls for research in the IB field have been made on the matter (Buckley and Casson, 2021; Ghauri et al., 2021; Luo and Zahra, 2023). Nonetheless, the literature lacks adequate focus on how SMEs can leverage digital transformation and sustainability for international success (Denicolai et al., 2021; Pham and Vu, 2024). Unlike larger firms, SMEs develop distinct strategic behaviors that influence their ability to adapt to market complexities and pursue growth strategies. Furthermore, the increasing global emphasis and pressures on sustainability (George et al., 2021) require SMEs to adopt green practices to compete effectively in this new environment. Thus, a clearer understanding of how SMEs navigate the

dual transformation of digitalization and sustainability is both theoretically and managerially significant.

The current qualitative study draws on nine case studies from established international firms operating in the Italian engineering industry, aiming to answer the following research question:

RQ: How do SMEs navigate different pathways of integrating digital transformation and sustainability, and how do these pathways influence their international competitiveness?

The study adopts the contingency theory as a theoretical lens (Donaldson, 2001; Lawrence and Lorsch, 1967) recognizing that there is no one-size-fits-all approach to integrating digital technologies and sustainability, and identifying key contingencies that influence the outcome of firms' strategic efforts for international competitiveness.

The paper makes three main contributions to IB research and practice. First, it advances international business theory by integrating digital transformation and sustainability within the same analytical framework, extending contingency theory to explain how context-specific factors shape the international competitiveness of SMEs. Second, it offers empirical insights by identifying distinct pathways through which SMEs combine digital and sustainable practices, thereby addressing the existing empirical gap on how this dual transformation unfolds. Finally, it provides practical implications for managers and policymakers by outlining actionable configurations of digital-sustainability integration that enhance SMEs' international competitiveness.

2. Theoretical Background

2.1. Digital Transformation and Sustainability: Definitory Aspects

Digital transformation is the integration of digital technologies into all business areas, including how companies operate and deliver value to their customers (Liu et al., 2024). It reflects a strategic response to the evolving technological and business landscape, with organizations seeking to leverage digital technologies to improve operations, elevate customer experiences, and sustain competitiveness (Kao et al., 2024). Digital transformation encompasses a set of actions related to the digitalization of firms, including the emerging concepts of Industry 4.0 and 5.0 (Ustundag and Cevikcan, 2017). At the core of Industry 4.0 is the intelligent combination of advanced enabling technologies such as big data analytics, cloud computing, artificial intelligence (AI), and the Internet of Things (IoT) (Culot et al., 2020; Frank et al., 2019). This interconnectivity enables firms to make informed decisions in real-time, enhance flexibility and efficiency, and maintain their competitiveness in global markets (Ciulli and Kolk, 2023; Ocelík et al., 2023; Xu et al., 2021). Industry 5.0 builds upon Industry 4.0 by placing a greater emphasis on human-centricity, sustainability, and resilience, underlying the role of enabling technologies such as individual human-machine interaction, digital twins, and AI (Xu et al., 2021). Besides several digitalization-related advantages (Dalenogare et al., 2018; Ocelík et al., 2023), businesses, and especially SMEs, face several challenges and risks when undergoing digital transformation (Broccardo et al., 2023; Denicolai et al., 2021; Luo, 2022), including investing in new technologies, developing new skills and capabilities, and changing organizational culture (Pham and Vu, 2024).

Sustainability represents the second disruptive element for international organizations (Ocelík et al., 2023; Oghazi et al., 2024). To thrive in a competitive business environment, companies are increasingly required to develop comprehensive strategies that enable economic sustainability and ensure the well-being of both people and the planet (Ferreira et al., 2023).

The traditional concept of sustainability is rooted in the Brundtland Report (Brundtland, 1987). Building on this foundation, the 17 Sustainable Development Goals, introduced by the United Nations General Assembly (United Nations, 2015), offer a universal agenda for sustainability, underlying the relevance of sustainable development. Beyond these fundamental definitions, sustainability profoundly models the process of internationalization by serving as a catalyst for competitive differentiation and market legitimacy (Li et al., 2017). For firms seeking to export, Corporate Social Responsibility (CSR) and eco-design offer a pathway to compete through value-added differentiation (Boehe & Cruz, 2010). Furthermore, sustainability acts as a critical entry ticket to developed markets. It grants legitimacy by meeting the pressures of MNEs regarding supply chain standards and satisfying the demands of consumers willing to pay a premium for ethically produced products (Guo et al., 2024; Marano et al., 2024). This engagement in global markets also enhances firms' capabilities through learning-by-exporting (Costa et al., 2015), allowing firms to internalize global environmental norms and mitigate risks associated with reputational damage or supply chain fragility (Li et al., 2017; Rao & Holt, 2005). However, this transition presents distinct challenges for SMEs, which must navigate the friction between immediate compliance costs and the long-term realization of market benefits (Zaman et al., 2025).

Digital transformation and sustainability, although distinct concepts, are increasingly intersecting in contemporary organizational strategies (Del Río Castro et al., 2021). Digital technologies, such as AI, IoT, and data analytics, enable firms to monitor resource use, optimize production efficiency, reduce environmental impacts, promote social inclusion, and overall support firms' performance and reputation (Broccardo et al., 2023; Dalenogare et al., 2018; Dantas et al., 2021; Del Río Castro et al., 2021). In turn, these impacts can boost global operations (Awan et al., 2022), drive innovation, and overall ESG performance (Liu et al., 2024). Conversely, sustainability imperatives often act as catalysts for digital innovation,

stimulating the development of green technologies and responsible production systems (Del Río Castro et al., 2021). In this sense, the integration of digital transformation and sustainability is complementary and mutually reinforcing, generating a dual transformation capable of improving firm resilience, legitimacy, and overall long-term competitive advantage (Rehman et al., 2023).

2.2. Two Strategies for International Competitiveness

The IB academic debate has increasingly focused on the impact of digital transformation on firms' international strategies and operations (Ferreira et al., 2023; Luo and Zahra, 2023; Patchell and Hayter, 2021; Ratten et al., 2024). Digital transformation enables international firms to streamline operations and improve efficiency, speed, and reliability (Dalenogare et al., 2018; Mustafa et al., 2024). It can reduce entry barriers to internationalization by providing cost-effective ways to reach and serve new markets (Brieger et al., 2022). Digital technologies enable data-driven decision-making and support real-time monitoring, which are key elements for firms operating across borders (Díaz-Chao et al., 2021; Oliveira et al., 2021; Strange and Zucchella, 2017).

Parallel to digitalization, sustainability has become critical in impacting IB activities as firms face growing pressure from stakeholders to reduce their carbon footprints and contribute to local communities (Dias Lopes et al., 2023; Patchell & Hayter, 2021). It imposes a logic of full-chain responsibility (Marano et al., 2024), extending firm accountability beyond internal operations to include the environmental and social performance of global suppliers. To mitigate systemic risks, firms must therefore actively transfer sustainability knowledge across borders and deeper integrate supplier activities (Rao & Holt, 2005). Moreover, the transition to regenerative models challenges the traditional logic of cross-border arbitrage (Yu et al., 2023). This evolution requires firms to coordinate the reduction of resource utilization while managing

renewable resources that are strictly localized. Consequently, sustainability imperatives demand investments and structural adjustments, particularly for international firms navigating customer, economic, and regulatory requirements and cultural expectations (Chabowski et al., 2023).

While digital transformation and sustainability have been mainly studied in isolation (Brieger et al., 2022; Chabowski et al., 2023; Hennart, 2019; Tiwari et al., 2024), recent literature emphasizes their complementary and integrative roles in achieving international competitiveness (Ferreira et al., 2023). Their integration can produce synergistic benefits, as digitalization can accelerate the adoption and measurement of sustainability initiatives, while sustainability can provide strategic direction for responsible and inclusive digital innovation (Broccardo et al., 2023). This complementary influence emerges in international operations, providing synergies that can streamline operations and demonstrate corporate responsibility, ultimately contributing to a competitive edge in global markets (Mustafa et al., 2024). In international contexts, companies that excel both in digital transformation and sustainability practices might better navigate the complexities of challenging competitive landscapes (Dias Lopes et al., 2023; Ferreira et al., 2023; George and Schillebeeckx, 2022).

IB research predominantly addresses the integration of digitalization and sustainability strategies from an MNEs perspective (George and Schillebeeckx, 2022; Liu et al., 2024; Patchell and Hayter, 2021; Srinivasan and Eden, 2021), underlying the role of MNEs in achieving sustainable practices and promoting digital technologies' diffusion across borders (Liu et al., 2024). While MNEs are frequently at the forefront of these transformations, the role of SMEs in leveraging digital tools and sustainable practices to sustain competitive advantage in international markets remains largely unexplored (Denicolai et al., 2021). In addition, the IB debate has focused on exploring these transformations from the perspective of companies entering new markets (Brieger et al., 2022; Luo, 2021). Therefore, a gap remains in

understanding how these transformative elements impact established international firms – those with a stable presence abroad that may need to maintain their international competitive advantage (Suh and Kim, 2014). The current qualitative study focuses on established Italian SMEs and their approaches to digital transformation and sustainability as pathways to sustain and enhance international competitiveness. To this end, we define international competitiveness as the firm's ability to establish a presence in global markets, achieve consistent growth, and maintain performance superior to that of its competitors over time (Cerrato and Depperu, 2011).

2.3. A Contingent Perspective on Strategy Integration

The study adopts a contingency theory perspective (Lawrence and Lorsch, 1967). Contingency theory provides a flexible framework that helps explain how internal and external factors shape companies' strategic choices (Van de Ven et al., 2013). It posits that there is no universally optimal way to strategy implementation. Instead, the effectiveness of a path depends on a firm's specific circumstances, such as its resources, structure, and the subenvironment (Donaldson, 2001; Lawrence and Lorsch, 1967). When applied to adopting digital transformation or sustainability practices, contingency theory suggests that companies adopt different approaches to these strategies based on their situational factors, including their competitive environment (Tiwari et al., 2024), and market demands for sustainability (Maletič et al., 2018). These strategic decisions are not mutually exclusive, and firms may adjust their levels of integration according to their specific contexts and perceived benefits (Maletič et al., 2018). Smaller firms, for instance, may adopt a phased digital transformation and sustainability approach to balance investment costs with international growth opportunities (Denicolai et al., 2021), focusing, for example, on digitally-enabled cost efficiency (Vanninen et al., 2022) rather than on proactive sustainability integration (Maletič et al., 2018). From a contingency perspective, integrating digital transformation and sustainability can thus be seen as a strategic configuration influenced

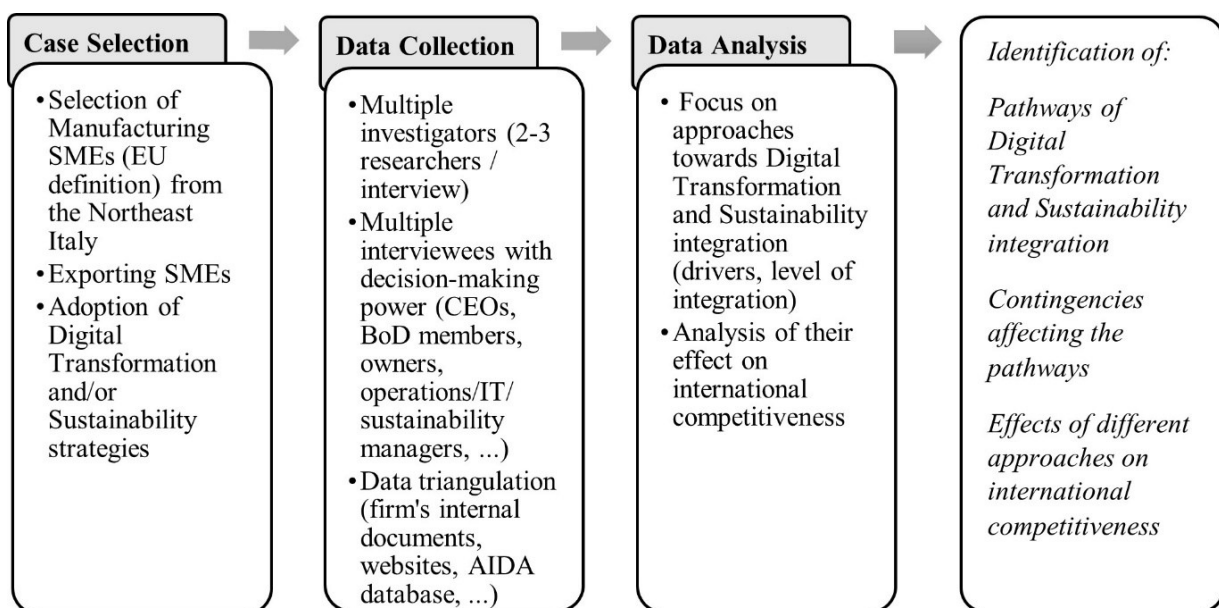
by contextual factors. Different combinations of these elements may lead to varying outcomes in international competitiveness, depending on the alignment between capabilities, environmental pressures, and firm-specific resources (Maletič et al., 2018; Szász et al., 2020).

3. Methodology

3.1. Research Context and Research Design

The research adopts a qualitative multiple-case study design (Yin, 2016) to investigate the pathways of digital transformation and sustainability for international competitiveness in the context of Italian SMEs (see Figure 3.1). This approach appears well-suited for addressing the research question, which emphasizes the need to understand the processes and strategies undertaken by the analyzed firms (Doz, 2011). Multiple case studies strengthen the validity of findings by allowing for cross-case comparisons and identifying patterns and variations across different SMEs and markets (Eisenhardt and Graebner, 2007). This choice enables a rich snapshot of how established international SMEs integrate digital transformation and sustainability to sustain international competitiveness.

Figure 3.1. Design of the multiple case study approach



3.2. Data Collection

Nine Italian manufacturing SMEs operating in Northeast Italy were purposefully selected (Poulis et al., 2013) to ensure the inclusion of information-rich cases that provide deep insights into the phenomenon under investigation (Eisenhardt, 1989; Patton, 2014). The focus on SMEs is widely justified. First, SMEs constitute the backbone of the European economy, representing a significant portion of businesses and employment positions (European Commission, 2003). Understanding their unique challenges and opportunities in integrating digital transformation and sustainability is crucial for promoting economic growth and competitiveness. Secondly, SMEs often present distinct characteristics, including limited resources, close relationships with stakeholders, and agility in decision-making (Pham & Vu, 2024), which create a unique context for examining the interplay between digital transformation, sustainability, and international competitiveness. Lastly, the focus on SMEs aligns with the increasing recognition of their importance in international markets, challenging the assumptions about the role of large MNEs (Vanninen et al., 2022). We selected SMEs according to the European Commission definition (European Commission, 2003), including firms with a turnover lower than €50 million. All selected firms were already active in international markets and had implemented relevant digitalization and sustainability initiatives prior to the study.

The data were gathered as part of the iNEST project (www.consorzioinest.it) which supports digital and sustainable transformation in strategic sectors through university-industry collaboration. To identify companies for this study, we: (a) leveraged prior research on digitalization and Industry 4.0 to pinpoint potential contacts; (b) engaged with technological parks and competence centers in Northeast Italy; (c) conducted extensive online research. This approach guided the selection process by drawing on academic, institutional, and independent sources for case identification (Farquhar et al., 2020). The selection focused on exporting companies in the engineering industry, providing a shared sectoral context for the study while

presenting internal variability in products, sectors, and target markets, thus allowing for greater internal validity and comparability across cases (Farquhar et al., 2020).

Data collection involved multiple forms of triangulation to enhance the trustworthiness of the findings (Patton, 2014). For each case, we combined several data sources, including multiple semi-structured interviews, company visits, press articles, company websites, sustainability reports, and archival data. This triangulated, multi-source approach increased the credibility of our findings by reducing reliance on single sources and enabling cross-validation.

We conducted multiple in-depth semi-structured interviews with key decision-makers (CEOs, Board of Directors members, entrepreneurs, operations/IT managers, sustainability managers) in each company (see Table 3.1).

A team of three researchers conducted each interview to enhance data reliability (Farquhar et al., 2020). Interviews were conducted between March 2024 and June 2025, mostly face-to-face at company premises, with a few sessions held online. Each interview lasted between 60 and 120 minutes, was recorded with participants' consent, and subsequently transcribed. The interview guide included open-ended questions designed to elicit detailed narratives about the research topics.

The interviews covered key themes, including the relevance of digital technologies, internationalization, and sustainability to the company's strategy, details about digitalization projects (initiated or planned), measurement of impacts and performance indicators related to digital transformation and sustainability, impacts on operational processes, products, and customer relationships, and the critical issues and challenges encountered. Websites, annual reports, and other public documents were analyzed to gather contextual information and triangulate interview data. Sustainability and ESG reports were particularly useful for cross-validating interview evidence on firms' environmental and social practices. Economic and financial data were retrieved from the AIDA database, which provides comprehensive

information on Italian firms, adding a quantitative layer to the qualitative analysis. Finally, company visits were organized. These latter provided direct observation of technology implementation, production processes, and sustainability practices, further supporting the credibility of our results (see Table 3.2).

Table 3.1. Primary data collection informants

Case	Industry	Firm size (employees 2023)	Firm size (turnover in millions of Euros)	Informants	Data collection detail
Dental	Engineering of medical instruments	40	10	Third-generation entrepreneurs, BoD, Sales Manager, Production Manager	2 interviews
Ironform	Manufacturing of metal structures	74	16	Second-generation entrepreneur, Sales Manager, BoD	2 interviews
Ironbrake	Manufacturing of metal products	88	20	Entrepreneur, Managing Director	2 interviews
Autoprecision	Manufacturing of metal products	39	11	Head of Accounting and Projects, CEO	2 interviews
Hi-tech metal	Manufacturing of precision machinery	69	12	Second-generation entrepreneur, Organization Manager, BoD	2 interviews
Ironknob	Manufacturing of metal products	63	13	General Manager	1 interview
Foodpack	Manufacturing of machinery for the food industry	101	28	IT Manager, Human- machine Interaction Manager, Sales Manager, Marketing Manager, Facility Manager	3 interviews
Coolingset	Manufacturing of non-domestic refrigeration and ventilation machines	83	33	Operations Manager, Sustainability Manager	1 interview
Hot washing	Production of cleaning machines	110	14	Vice-president, CEO	1 interview

3.3. Data analysis

Data analysis was conducted through an iterative and rigorous process, following the principles of qualitative data analysis (Doz, 2011). Interview recordings were transcribed verbatim. All qualitative data, including interviews, reports, websites, and field notes, were imported into NVivo software for systematic analysis.

Table 3.2. Case companies' main characteristics

Case	Main production	Internationalization	Technology adopted	Sustainability initiatives
Dental	Engineering and production of high-quality dental instruments	90% export (EU, North America, Asia, Africa, Oceania)	ERP, automated production (I4.0 machinery), product traceability, CRM, vertical warehouse	Environmental certification (FSC), recycling, employee welfare, photovoltaic system, ISO 14001, forest project, charity
Ironform	Sheet metal processing for the mechanical industry	50% export (EU)	Interconnected machinery, BI, co-bots, skill matrix, ERP, I4.0 machinery	Energy efficiency, production efficiency
Ironbrake	Production of components for the automotive sector	70% export (EU)	MES, EDI, simulation software, vision system, and marking	Energy-saving, reduced material waste, recycling, carbon footprint calculation model
Autoprecision	Precision components for the automotive industry	60% export (EU)	Automated production, system integration, 3D printing, and visualization	Energy optimization, air filtration, waste reduction, recycling, ISO 14001, photovoltaic system, ESG reporting
Hi-tech metal	Hi-tech production of precision machine parts and small assemblies	70% export (EU)	ERP, MES, vertical warehouse, system integration, BI, 3D printing, sensors, autonomous robots	ESG reporting, carbon footprint and sustainability assessment, waste reduction, ISO 9001, 14001, 45000
Ironknob	Design and manufacturing of aesthetic aluminum finishes	70% export (EU, Asia)	System integration, 3D printing, cloud, robots, simulation, IoT sensors	B Corp, ISO 50001, recycling, efficient use of materials and energy, transparency and reporting, supply chain engagement
Foodpack	Design and manufacturing of filling machinery for the food industry	80% export (EU, North America, Asia, Africa)	3D printing, augmented reality experiences, data analytics, cloud, system integration, IoT, AI (chatbot), B2B e-commerce platform	B Corp, LEED certification, water recycling, ESG reporting, employee welfare, energy efficiency, green energy use, waste reduction, sustainable material sourcing
Coolingset	Design and manufacturing of dry coolers and condensers for industrial use	90% export (EU, North America)	Co-bots, 3D printing, system integration, BI, MES, production planning software, remote machine monitoring, co-bots, WMS	Energy and water efficiency, sustainability committee, sustainability plan, emission reduction, supply chain engagement, health and safety initiatives, employee engagement
Hot washing	Design and manufacturing of industrial and professional washing machines	75% export (EU, North America, Asia, Africa)	Cloud, autonomous robots, big data analytics, GSM, automated warehouse, after-sales support chatbot	Water and energy monitoring, recycling, employee welfare, charity, supply chain engagement, sustainable knowledge sharing, energy efficiency

We adopted an inductive analytical approach (Eisenhardt, 1989), allowing patterns and relationships to emerge directly from the empirical data. The coding process was iterative, aiming to identify recurrent themes and develop conceptual categories grounded in the evidence collected. The coding structure was progressively refined and organized around key analytical dimensions – digital transformation, sustainability, and international competitiveness. The codes were built in NVivo and were structured hierarchically to reflect relationships between contingent factors (internal and external), drivers of and impacts on international competitiveness, digitalization, and sustainability initiatives, and their integration (Ghauri and Firth, 2009). The coding process allowed for the identification of key themes and patterns.

The collected data were thoroughly analyzed. This involved systematically reviewing the data, identifying recurring patterns, and grouping them into broader thematic areas that reflected the study's guiding questions. Table 3.3 synthesizes these dimensions, presenting, in addition to themes and subthemes, illustrative interview statements. Finally, a cross-case analysis was conducted to compare the findings across the nine cases (Yin, 2016).

Measures were taken to ensure the trustworthiness and quality of the research findings. Firstly, we achieved researcher triangulation through the involvement of multiple investigators, allowing for the development of multiple perspectives on the collected data (Eisenhardt, 1989; Yin, 2016), reducing the risk of individual bias. Secondly, we employed data triangulation by utilizing multiple data sources for the cross-validation of information (Yin, 2016). Finally, detailed descriptions of each case, the identified integration pathways, and the data analysis process were provided to strengthen the transferability of the findings and allow for research replicability.

Table 3.3. Summary of key themes and subthemes emerging from the study

	Themes	Subthemes	Examples: Interview statements
Contingencies	External Contingencies	Competitive Environment	<i>“Among German firms, those that remain are about our size, while the American ones are much larger. There’s a clear market trend of increasingly large conglomerates.”</i> <i>“The goal of these projects is to compete with companies that are hundreds of times bigger than us – those with tens of thousands of employees and extensive global after-sales networks, which we do not have.”</i>
		Market Dynamics	<i>“We are talking about codes of conduct and ethical codes – for everything, you must have supporting documentation. This leads to a rating system through which clients evaluate you and set goals.”</i> <i>In reality, our investments are guided directly by our clients, who show us the direction. We interpret that direction and align our investments accordingly.”</i>
		Technological Landscape	<i>“Maintaining an efficient internal department with machinery also requires investment – at some point, technology advances, CNC machines improve, and you need to replace older equipment. These are inevitable investments.”</i> <i>“We had to implement technology across all departments, not just some, and ensure that data was fully available. We preferred to wait an extra year and go through a longer process because digitalizing all our old machinery was complex.”</i>
	Internal Contingencies	Capabilities & Resources	<i>“The technology is there, but you need capable people who can effectively use these technologies.”</i> <i>“We have two people working in management control, and we’ve always done that, even before the digital era. One of them was trained specifically in Power BI management.”</i>
		Economic and Product Considerations	<i>“Clients have specific thermal exchange requirements, and we design the machine accordingly. There is a high level of variability, so we are also working on standardization to reduce it and become more efficient.”</i> <i>“Our focus, and this has been our strategy for the last ten years, is on niche sectors that require a certain technological standard: Medtech, Optomechanics, Aviation – industries with specific technological needs.”</i>
		Human Capital	<i>“It’s extremely difficult to find qualified personnel. We’ve collaborated with schools [...]. We even hired people who had never seen a technical drawing before and trained them from scratch.”</i> <i>“We hired an engineer to follow all our innovation projects. The goal was to achieve daily management of [digitalization projects] and of digital training activities.”</i>
		Organizational Structure Strategic Orientation	<i>“For the last two years, we have been part of the biggest European group in our sector.”</i> <i>“We are a family firm entering the third generation. The company was founded by our grandfather in the knife district.”</i> <i>“The decision [to progress our digital transformation] was not driven by survival, but by awareness – we can’t stand still; we must move forward.”</i> <i>“When investing in digitalization, we didn’t calculate ROI beforehand – only afterward did we see the impacts. The investment had to be made; we couldn’t present ourselves without it. It was a matter of service, both for our [international] clients and internally, to show our people that the company is evolving.”</i>
Drivers	Sustainability-Related Drivers of International Competitiveness	Brand Differentiation via Sustainability	<i>“There is also a matter of credibility with the [multinational] customer, so that any misstep could damage the brand reputation.”</i> <i>“Sustainability is now a commodity; therefore, if you are not compliant, you cannot survive in the [international] market. Understanding how to develop a distinctive positioning on the matter is a challenge.”</i>

Table 3.3. (Continued)

Impacts	Technology-Related Drivers of International Competitiveness	Cost Optimization via Sustainability	<i>"We developed a project that leverages technology and smart meters to reduce energy waste."</i> <i>"This enabled us to cut the number of trucks collecting and transporting waste by nearly 50% per year, which is a very significant result."</i>
		Market-Driven Sustainability	<i>"In some cases, all these steps become prerequisites to work with certain [foreign] clients. For instance, in 2018, we obtained the ISO 14.001 certification, which is uncommon for a company of our size, because we move based on [international] clients' requirements."</i> <i>"Today, [multinational] clients use various tools, and one that's gaining traction is EcoVadis, a supply chain evaluation platform used by some of our customers, who asked us to align with it."</i>
		Cost Optimization via Digital Transformation	<i>"All the automations and robotizations allowed us to implement the unsupervised night shift. It is the night shift that allows an immediate lowering of costs [...] and it is the one that helps rebalance all other production costs."</i> <i>"[Thanks to the Industry 4.0] the performance of our machines has improved, and this allows us to be more efficient and provide our [global] customers with better prices."</i>
		Digital Transformation as a Long-Term Competitive Asset	<i>"In our view, these are tools you must have. Nowadays, even appliances worth €500 come with smart features – how could you not have them on a €500,000 industrial plant? It's unthinkable. Maybe I can accept that, but my son's generation won't buy a machine without such a service. So either you adapt now, or you'll no longer be competitive – when the need arises, it'll be too late."</i> <i>"Having new machines means a lot, because [our international clients] know we can perform better and be achieve higher energy efficiency [...] and this is all taken into account [by our customers]."</i>
		Digital Efficiency & Productivity	<i>"In the end, [digital transformation] translates into a benefit for the company, as you achieve greater production efficiency."</i> <i>"As for the planning system, we moved from an on-time delivery rate to our clients of about 45% to just above 80%, and it's still improving."</i>
		Strategic Investment in Digital Transformation	<i>"In 2021 and 2022, with investment [in digital innovation] equal to 14% and nearly 18% of revenue, we gave an extra push because we knew there were incentives available that might not last. Since for our production type and for our [international] market positioning, innovation is a non-negotiable, we had to go in this direction."</i> <i>"A lot has changed [in our strategy]. In 2022, we completely overhauled our machinery by investing in Industry 4.0."</i>
		Other Drivers of International Competitiveness	<i>"Concerning internationalization, it is not digitalization that can help or hinder the process, but rather, in our sector, the main issue is the regulations. The European MDR law, which we've been working on for years, creates extremely high entry barriers."</i> <i>"Large [multinational] companies, even if not committed to doing so, may be forced to consider what their supply chain does and, therefore, differentiate between those [supply chain members] that behave well and those that misbehave [...]."</i>
		Impacts on International Competitiveness	<i>"[The project we developed to connect our machines remotely to our clients] went well, in the sense that we managed to implement it, and the EDI allowed us to be connected in real time with some clients. In this case, it's the client who requests it, and so you have to set yourself up in such a way that your ERP can handle the information that the client needs."</i> <i>"Our manager worked for years to develop the entire CRM system to better manage order progress and provide timely responses to customers. One of the main customer disappointments is being given a delayed delivery of the machinery. This is something we learned years ago, through our continuous improvement project."</i>
		Customer Value & Differentiation	

Table 3.3. (Continued)

Integration Levels	Level of Integration	Financial & Economic Impact	<i>“Despite everything [like growing energy costs and global challenges], thanks to all the investments made in digitalization, we’ve managed to maintain an annual 1,5% point increase in EBITDA.”</i> <i>“We’ve already seen a clear economic return from the e-portal – our B2B spare parts platform generates €4 million in annual sales, with no back office and zero errors.”</i>
		Market & Sales Performance	<i>“We found new [international] clients, because now we supply finished products, and we were able to go back to clients that were looking for these finished products. Before that, we were forced to exclude them, since we didn’t want to invest in changing our production.”</i> <i>“Now I can plan the production at light speed [...] to be more responsive towards the customer inquiries. From this point of view [digitalization] allowed us to be more responsive.”</i>
		Operational & Strategic Resilience	<i>“Yes, that has definitely allowed us to sell machines abroad even during the COVID pandemic, and to provide service where we don’t have technicians. Augmented reality and similar tools help a lot, for sure.”</i> <i>“Since the pandemic, we have decided to work directly with tier-1 [multinational] suppliers and provide finished products, developing a fully integrated production process.”</i>
		Reputation & Brand Image	<i>“What we need to guarantee, in addition to a certain corporate image, is this sense of reassurance. The customer must feel confident they are working with a company that pays great attention to hygiene and safety.”</i> <i>“Investments in technology are recognized [by multinational customers] because they improve reliability as well as the structure and quality of the product.”</i>
		Co-design of Digital Transformation & Sustainability Initiatives (High)	<i>“Industry 4.0 linked to sustainability will certainly help reduce waste – even for clients, such as replacing a cap every 1,500 hours instead of 1,000. That means fewer materials discarded at the end of life and a service tailored to customer needs.”</i> <i>“[Digital transformation and sustainability initiatives] made us more aware [of our management and performance], and we see this is very much appreciated by the customers, because sometimes, we are ahead of our clients. In fact, they are the ones who ask what we have already done [in terms of sustainability]. This way, we also become a point of reference, and there is mutual exchange.”</i>
		Digital Tools Enabling Sustainability (Low)	<i>“Remote assistance definitely contributes to a more sustainable approach – no flights, no travel.”</i> <i>“Digital technology helps track sustainability, monitor data, and then define development plans.”</i>
		Sustainability-driven Tech Adoption (Low)	<i>“We have not put technology first, but rather the objectives related to the sustainability of our business in the future.”</i> <i>“For example, we’ve equipped ourselves with a range of sensors and measuring devices distributed throughout the company to monitor energy consumption. Since they communicate with the cloud, we’re using them to implement energy monitoring processes.”</i>
		No Synergies (Parallel Operations)	<i>“Investments in technology are recognized because they improve the reliability, as well as the structure and quality of the product. Investments in sustainability, at the moment, are recognized more by other stakeholders, such as suppliers, rather than credit institutions, insurance, even if we have some clients who ask not for data, not for detailed reports, not for sustainability reports, but what the company is doing regarding ESG issues.”</i> <i>“What is meant by servitization?”</i>

4. Findings

The data analysis identified four distinct integration pathways (see Figure 3.2), providing a framework for understanding the different approaches Italian SMEs take to combine digital transformation and sustainability for international competitiveness: digital transformation-led approach, sustainability-led approach, parallel approach, and integrated approach.

These pathways emerged by systematically grouping firms based on the relative emphasis, sequencing, and level of integration between their digital and sustainability initiatives. Each demonstrates unique drivers, levels of integration, and impacts on international competitiveness, revealing how varying degrees of synergy influence SMEs' success in the international markets.

This approach enabled a focused examination of how firms adopt different strategies in response to sectoral requirements, regulatory constraints, market expectations, and technological resource availability. Each pathway reflects a strategic alignment, or lack thereof, between digital transformation and sustainability, shedding light on how these efforts collectively or independently support the firm's international goals. The categorization of the analyzed cases into the four pathways is summarized in Table 3.4.

Figure 3.2. Approaches to digital transformation and sustainability integration for international competitiveness

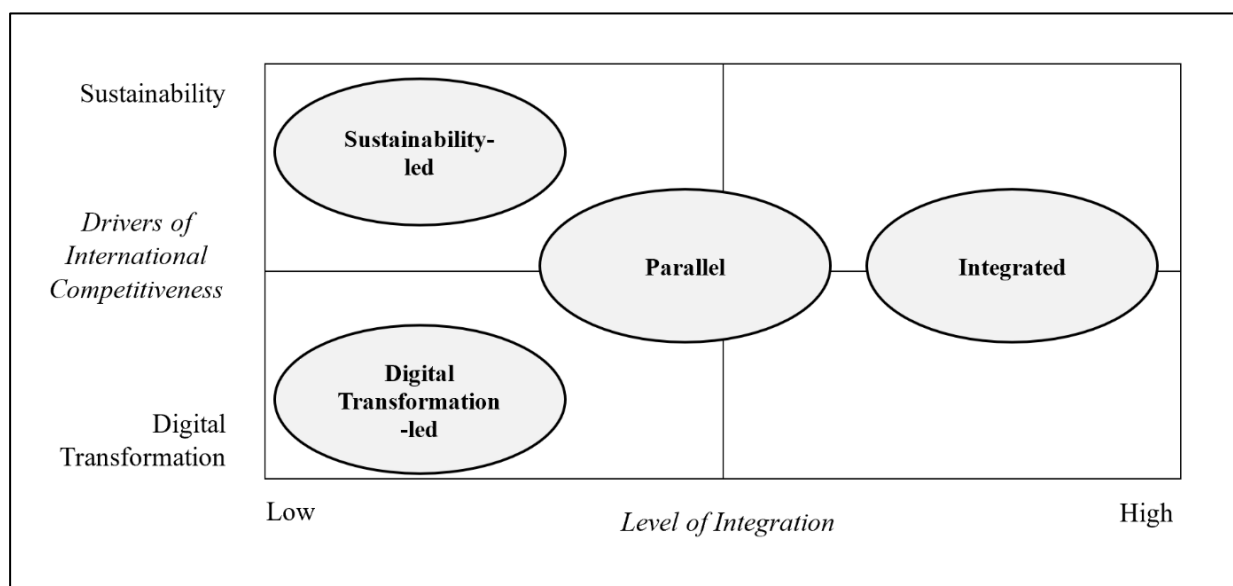


Table 3.4. The four approaches' main characteristics and relevant cases

Approach	Drivers of International Competitiveness	Level of Integration	Relevant Cases
<i>Digital Transformation-led</i>	Digital Transformation	Low	Ironform
<i>Sustainability-led</i>	Sustainability	Low	Ironbrake
<i>Parallel</i>	Both, in parallel	Low to Medium	Dental Ironknob
<i>Integrated</i>	Both, in an integrated way	High	Hot Washing Coolingset Autoprecision High-tech Metal Foodpack

4.1. *Digital transformation-led approach*

In the digital transformation-led approach, SMEs prioritize digital transformation as the foundation of their strategy, focusing primarily on leveraging technological advancements to enhance efficiency, productivity, and responsiveness. Initiatives in this pathway often include deploying enterprise resource planning (ERP) systems, adopting interconnected machinery, and investing in Industry 4.0 technologies like IoT, co-bots, and advanced data analytics. In contrast, sustainability benefits are a secondary outcome of these initiatives and are not the primary strategic driver. Digital transformation-led firms perceive international competitiveness to stem from improvements in speed, cost reduction, and service quality

The Ironform case exemplifies this approach. In 2022, Ironform overhauled its machinery, adopting new Industry 4.0 technologies such as interconnected equipment, business intelligence (BI) analytics, co-bots, and ERP systems. This transformation has enabled the company to significantly reduce production times and enhance output quality, directly contributing to its competitive positioning in the European market. According to the firm's sales manager, the transformation has focused on enhancing production speed and accuracy. These improvements directly align with Ironform's strategic focus on digital transformation as a driver of efficiency, price competitiveness, and international market positioning. A similar pattern can be seen in the Ironbrake case. The company employed a manufacturing execution system (MES) that connects machinery, allowing real-time data collection and analysis across

all production stages. The system increased operational efficiency and traceability, improved responsiveness to production issues, and reduced waste.

“Now, with the MES system, we have pushed traceability to almost the individual piece.” (Case Ironbrake, General Manager)

The contingencies guiding the digitalization-led approach include customer demand, competitive pressure, and internal expertise, each shaping their strategies to support international competitiveness. Customer demands, particularly from MNEs, increasingly emphasize the role of advanced digital technologies and energy-efficiency solutions in supply chains, pushing SMEs to adapt to customers' requirements. For both firms, the visibility of interconnected machinery and the adoption of Industry 4.0 enhances market reputation and credibility with foreign clients, signaling technological sophistication and reliability.

Competitive pressures represent another driving force of change. Operating in highly competitive international markets, the companies have leveraged cutting-edge digital investments to differentiate themselves. For Ironform, leveraging Industry 4.0 machinery has enabled the company to increase output and offer more competitive pricing, making it more attractive to international clients.

“Having certain machines, which the customer knows about, allows us to be well-considered by them; they know that the machines are more efficient, and we can increase the output and come out with more advantageous prices.” (Case Ironform, Sales Manager & BoD member)

Companies' digital transformation has expanded international market access, enabling firms to acquire new foreign clients who value technologically advanced and reliable suppliers. For instance, Ironbrake has utilized digital systems to enhance production efficiency and traceability, thereby meeting the stringent demands of Tier 1 automotive suppliers. The

company recognizes the importance of digital investment in maintaining its competitive position.

“Technology and investment in machinery [are drivers of competitiveness]. [...] In 2022-2025, we will invest about 6 million euros in machinery.” (Case Ironbrake, General Manager)

A further critical contingency is internal expertise. Ironform has relied on skilled team members with IT and management skills to optimize data flow, improving decision-making and productivity.

This approach considers sustainability a supplementary benefit rather than a primary goal. For instance, installing new machinery resulted in indirect energy savings. This pathway has been identified in metalworking and metal components production companies, where technological advances and production speed are prioritized for market positioning. Sustainability, though acknowledged, is not yet central in their strategic framework and is framed in terms of cost reduction and operational efficiency rather than as a distinct, stand-alone objective.

4.2. Sustainability-led approach

In the sustainability-led approach, companies prioritize sustainability initiatives as the cornerstone of their strategy, focusing on ecological and social responsibilities as critical drivers of competitive advantage. This approach is commonly adopted in sectors where environmental regulations, brand differentiation, and customer expectations for sustainability are particularly strong. For these companies, international competitiveness stems from compliance with global sustainability standards, enhanced brand reputation, and the ability to reduce supply chain risk. Ironknob, a manufacturer of aesthetic aluminum finishes, exemplifies this approach through its dedication to environmental standards and sustainable business practices. As a certified B-

Corporation and ISO 50.001-compliant company, Ironknob focuses on recycling, energy efficiency, material optimization, and supplier engagement. Sustainability, rather than digital transformation, is the guiding principle of its long-term strategic orientation.

“When making our plans, we rely on objectives that are not directly digitalization or Industry 4.0, but rather objectives linked to the five pillars of sustainability, which we consider to be the beacon on which we build our strategy. [...] We have not put technology first, but rather the objectives related to the sustainability of our business in the future.” (Case Ironknob, General Manager)

Similarly, the Dental case demonstrates a commitment to ecological responsibility, social engagement, and long-term resilience, achieved through sustainable materials sourcing, energy-efficient production, and waste reduction. In both cases, sustainability is an inherent part of their brand identity, particularly in international markets that are increasingly sensitive to ethical and environmental issues.

“[Sustainability efforts] did not come from a market demand, but from our own desire, our approach, our philosophy. We have always been excessively attentive to sustainability aspects.” (Case Dental, Third-generation entrepreneur & Production Manager)

These firms view sustainability as a way to strengthen resilience against global geopolitical, environmental, and market-related disruptions by increasing organizational flexibility and long-term stability. By aligning with global sustainability standards and demonstrating ethical behaviors, the companies were able to fortify their market position. Though not always directly driven by customer demands, the sustainability efforts reflect a forward-thinking approach to navigating an increasingly sustainability-conscious global context. This strategic orientation enhances international competitiveness by aligning with

emerging regulatory pressures (e.g., EU sustainability disclosure requirements) and the growing tendency of large multinationals to seek certified and responsible suppliers.

“Presenting ourselves as a sustainable company is a guarantee from the practical point of view of business continuity and the reduction of risks [...]. There is also a matter of credibility towards the consumer [...]. Large [multinational] companies, even if not committed to doing so, may be forced to consider what their supply chain does and, therefore, differentiate between those [supply chain members] that behave well and those that misbehave [...]. From this point of view, we expect to gain some [competitive] advantages” (Case Ironknob, General Manager)

A key driver of competitiveness for sustainability-led firms is flexibility and organizational adaptability, which supports resilience and responsiveness to international customers. This allows firms to compete in international markets without relying on cost-based advantages. Instead, they leverage industrial culture and relational capacity.

In firms adopting a sustainability-led approach, the use of digital technologies is selective and supportive rather than transformative. Technologies are implemented when they are clearly linked to sustainability or customer value creation, and are regarded as an added cost otherwise. For example, Ironknob utilizes digital technologies to enhance operational efficiency and track resource use, but these are instrumental to the overarching goal of sustainability. This selective approach to digital transformation aligns with the firm’s strategic emphasis on creating a workplace that values ergonomics, safety, and flexibility for its workforce, sustaining its human capital.

“Our primary objective was to create a workplace that made life very easy for the operator [...] There was no objective of digitalization; there was an objective to create the first workplace suitable for the people of our time.” (Case Ironknob, General Manager)

In contrast, Dental highlights how regulatory compliance, rather than digitalization, determines international competitiveness.

“Concerning internationalization, it is not digitalization that can help or hinder the process, but rather, in our sector, the main issue is the regulations.” (Case Dental, Third-generation entrepreneur & Sales Manager)

By proactively aligning with sectoral regulations, the company positions itself to navigate the evolving international landscape, where regulatory adherence is the primary driver of competitive advantage.

The impacts of global disruptions, including Covid-19 and geopolitical events, can drive these companies to prioritize sustainability as a stabilizing factor. Organizations can respond to these shocks by increasing flexibility, making daily adjustments to resource allocation, and ensuring operational resilience and responsiveness towards international clients. Furthermore, by implementing employee welfare and workplace ergonomics, these companies address structural challenges related to an aging workforce and the shortage of technical skills, reinforcing long-term organizational adaptability. Overall, this pathway enables firms to strengthen their resilience and credibility in international markets while positioning themselves as credible international players.

4.3. Parallel Approach

The parallel approach describes a pathway where firms actively pursue digital transformation and sustainability initiatives, yet these efforts remain largely independent and uncoordinated. Companies following this trajectory acknowledge the strategic relevance of both strategies for enhancing international competitiveness, but typically implement them as separate responses to distinct market pressures, regulatory demands, or technological opportunities.

Firms such as Hot Washing and Collingset exemplify this pattern. On the one hand, digital transformation initiatives are primarily focused on enhancing operational efficiency, customer experience, and product customization, which serve as key levers of competitiveness in international markets. As Hot Washing's Vice President and CEO noted:

"The high customization [is our competitive advantage]. [...] In 2019, we launched a new programmer for washing machines that can be connected via Wi-Fi, and therefore, when the machine is online, it is visible to us in real time. [...] We are interested in [the data] for reviewing the product, for redesigning it." (Case Hot Washing, Vice President & CEO)

Similarly, Coolingset has leveraged digitalization to enhance planning systems and customer responsiveness. The implementation of new planning processes has significantly improved service time and delivery reliability, which are now crucial international competitive factors:

"The introduction of the planning system led to the creation of a new process [...]. Customers now receive constant feedback on service times, and they appreciate it. Delivery time today is fundamental – cost is negotiated upfront, and quality is undisputed." (Case Coolingset, Operations Manager)

While digital initiatives primarily target efficiency and market differentiation, sustainability efforts are often driven by regulatory compliance, stakeholders' expectations, and cost reduction goals. These include actions such as energy optimization, waste minimization, pollution prevention, and employee well-being programs. For Hot Washing, sustainability translates into adapting products to meet diverse international standards and environmental regulations – an effort often treated as a market-specific requirement rather than a strategic integration with digital goals. Similarly, Coolingset highlights how sustainability has become

an increasingly decisive factor in international competitiveness, especially when entering high-regulation markets, such as those involving nuclear cooling systems.

“Sustainability is now a commodity, so if you are not compliant, you cannot even be on the market.” (Case Coolingset, Operations manager)

External stakeholders play a crucial role in pushing these agendas. Investors are increasingly inquiring about sustainability practices as part of their risk management assessments. Meanwhile, large international clients are explicitly requesting information on CO2 emissions, pollution, and environmental certifications before approving new suppliers. These external pressures reinforce the strategic importance of sustainability for maintaining and expanding international market access.

Companies adopting the parallel approach recognize the interconnectedness of digital transformation and sustainability, yet they struggle to translate it into a coordinated strategy. Organizational and ownership structures often reflect this separation, with dedicated teams and distinct goals, budget, and objectives for each domain. In many cases, sustainability is managed primarily at the corporate or strategic level, while technological initiatives are confined to the operational sphere. This separation limits opportunities for synergy and strategic coordination, constraining the firm’s ability to leverage digital capabilities in support of sustainability objectives, and vice-versa.

Market demands and competitive pressures also shape how firms prioritize and implement digital transformation and sustainability strategies. For instance, Hot Washing introduced digital products as a market necessity, recognizing that competitors had already adopted similar solutions. Coolingset, by contrast, pursued digital transformation to improve planning processes, service reliability, and customer responsiveness, with projects focused on efficiency gains rather than integration with sustainability goals.

Limited financial availability and segmented organizational structures can hinder the development of integrated digital transformation and sustainability strategies. Challenges can arise from the difficulties of managing complex projects with limited internal resources, which often require external support or additional investment capacity that may not be readily available. As the Hot Washing case emphasizes, the costs associated with sustainability initiatives are significant and sometimes underestimated:

“It is a cost [working on sustainability projects] [...] The time may not be accounted for, but it is time taken away from our main activities.” (Case Hot Washing, Vice President & CEO)

Despite these constraints, both companies leverage digital transformation to enhance product functionality, optimize production processes, and improve customer service – key factors that strengthen international competitiveness. Simultaneously, sustainability initiatives enable them to meet international standards and respond to growing global demand for sustainable products. The lack of strategic integration between these two strategic dimensions can be attributed to both internal and external contingencies, such as resource limitations and organizational silos, sectoral regulations, or client-driven requirements. Nevertheless, the parallel approach may reflect a transitional phase in the journey of SMEs. By recognizing the distinct drivers and specific contingencies shaping digital transformation and sustainability, companies can begin to bridge the gap between these domains, unlocking their combined potential to enhance international competitiveness.

4.4. Integrated Approach

The integrated approach represents a more advanced stage in digital transformation and sustainability implementation. Companies following this pathway strategically combine digital technologies and sustainable practices, leveraging their synergy to drive innovation, enhance

competitiveness, and foster sustainable growth. In this pathway, integration is primarily driven at the strategic level. The company's leadership shows a holistic vision, deliberately framing digital transformation and sustainability as a joint response to international competitive pressures, rather than as separate or sequential priorities. Companies leverage digital transformation to enable and enhance their sustainability efforts while recognizing how sustainability considerations can drive digital innovation and showcase a clear strategic alignment between the two. They demonstrate a proactive mindset, anticipating future trends and challenges and leveraging digital tools and sustainability to build resilience and competitive advantage. Furthermore, they use technologies to optimize processes, reduce emissions, enhance efficiency, productivity, and customer service, and improve sustainability performance. Here, process integration emerges because of strategic integration, as firms select and deploy technologies that simultaneously address efficiency and sustainability goals. For instance, in the Autoprecision case, the company demonstrates a clear focus on utilizing technology to optimize resource consumption and minimize its environmental footprint. The company has invested in various digital technologies, including automated production, system integration, and 3D printing and visualization, to improve efficiency and sustainability. At the same time, their commitment to the environment is evident in their energy optimization and waste reduction initiatives, enabled by digital technologies, as well as in obtaining the ISO 14.001 certification and implementing ESG reporting.

Hi-tech Metal and Foodpack offer additional relevant examples of this pathway. Hi-tech Metal views digitalization as fundamental to operating in its high-tech sector, enhancing efficiency, quality, and responsiveness to customer demands. Its commitment to sustainability has strengthened its reputation with multinational clients, who increasingly require certified, environmentally responsible suppliers.

“We are not required to draw up a sustainability report, but we work with MNEs that need a certified supply chain that respects certain parameters.” (Case Hi-tech Metal, Second-generation entrepreneur & Organization Manager)

The company recognizes the interconnectedness of digitalization and sustainability strategies, highlighting the role of digital transformation in reducing waste and enhancing sustainability. This interconnectedness reflects a strategic choice rather than a purely technical one, as sustainability considerations inform digital investment decisions aimed at maintaining global competitiveness.

A comparable synergy between digital transformation and sustainability emerges in Foodpack, where a strong organizational culture, technological innovation, and environmental awareness form the foundation of its strategic differentiation and competitive advantage. Also in this case, integration originates from top management’s vision of how operational excellence, corporate image, and environmental responsibility jointly support international market positioning.

“Our President has always believed in this philosophy [...]. We distinguish ourselves because our company is always tidy and clean. [...] If the customer perceives a certain philosophy, they have an almost certain high-quality expectation for our machines. [...] What we need to guarantee [to the customer], in addition to a certain corporate image, is this sense of reassurance. The customer must feel confident they are working with a company that pays great attention to hygiene and safety.” (Case Foodpack, Facility Manager)

The growing demand for sustainable products and services from customers and stakeholders, as well as the need to remain competitive in a globalized market, are critical drivers for these companies to integrate digital transformation and sustainability. Advanced technologies, including Industry 4.0 solutions, provide tools to optimize processes, collect and

analyze data, and monitor sustainability performance. Integrating sustainability and digital strategies positions companies as forward-thinking leaders in both domains. For example, the High-tech Metal case illustrates a story of effective competitive positioning. Their digital transformation improved operational efficiency and enhanced their sustainability reputation, which has proven crucial in securing multinational clients and strengthening their brand and global positioning while staying ahead of the competition.

“Sometimes, we are ahead of our clients. In fact, they are the ones who ask what we have already done [in terms of sustainability]. This way, we also become a point of reference, and there is mutual exchange. (Case High-tech Metal, Second-generation entrepreneur & Organization Manager)

Foodpack, on the other hand, employs digital monitoring and automation to ensure precision, reduce waste, and guarantee safety standards, thus strengthening its organizational and relational capital. The digital-sustainable integration enabled the firm to develop new business models and service offerings. Its B2B e-commerce for spare parts – generating around €4 million annually – demonstrates how digital tools streamline operations, reduce errors and resource utilization, improve efficiency, thereby integrating sustainable practices with structural capital development.

Leadership commitment and organizational culture are crucial factors in choosing this approach, acting as the central enabling mechanism through which integration is initiated and sustained. Companies with strong leadership and a clear vision are better positioned to align their digitalization and sustainability efforts.

“Digitalization has been an almost natural progression [...]. Regarding sustainability [...], some practices are already part of our daily operations. For us, it was normal to be at this [advanced, A-tier] level.” (Case High-tech Metal, Second generation entrepreneur, Organization Manager & BoD member)

“Of course, the commitment of the company’s ownership is fundamental. [...] Right now, we have two people working on this [digital transformation] area, plus me providing IT support, my colleague focusing on AI, and strong backing from the ownership.” (Case Foodpack, IT Manager)

Firms demonstrating an integrated approach generally possess a high level of awareness regarding the combined impact of digital transformation and sustainability on international competitiveness. However, such awareness was not immediate. Rather, it evolved as companies recognized how integration could significantly enhance their global positioning. This confirms that integration develops progressively, following strategic choices rather than preceding them. This is the case for High-tech Metal and Foodpack. The companies have undergone a sustainability assessment, earning respectively an A rating and an Ecovadis Bronze medal (upgraded to Silver within months, with the goal of achieving Gold) without implementing additional measures. At the same time, digitalization has proven a necessary condition for competitiveness.

The integrated approach represents a more mature path for international SMEs. By aligning digital and sustainability strategies with business objectives, firms can unlock synergistic value that fosters long-term success. Leadership commitment and strategic orientation toward international competitiveness are the primary drivers of this approach. Internal pressures, such as organizational culture, and employee engagement, as well as external factors including market demands, technological advancements, and competitive pressures, act as reinforcing mechanisms, empowering SMEs to navigate the complexities of a global business environment.

5. Discussion

The case analysis reveals that digital transformation and sustainability are not necessarily complementary or convergent in all contexts but can operate independently, complementarily, or in synergy, depending on the firm's specific contingencies. This diversity of configuration underscores the argument that there is no optimal pathway to international competitiveness. Instead, each presents a context-specific means of competitive positioning that responds to the firm's unique external pressures, internal resources, and strategic goals (Lawrence and Lorsch, 1967; Van de Ven et al., 2013) (see Table 3.5).

The digital transformation-led pathway focuses on operational efficiency, speed, and cost reduction, where digitalization is the primary driver of international competitive advantage. The link between digitalization and sustainability is often indirect and does not always enhance the company's international positioning. Environmental benefits may emerge as byproducts of technological advancements aimed at streamlining operations, or, conversely, as additional costs. While digital tools and interconnectedness of production systems can improve resource efficiency by optimizing workflows, reducing material waste, and managing energy use, achieving compliance with sustainability standards may require investments that do not directly contribute to operational gains (Denicolai et al., 2021). Thus, sustainability benefits are secondary to digital priorities and are usually not formalized. In highly competitive, efficiency-driven sectors, digital transformation alone can still provide a valid route to international competitiveness by addressing core needs for speed and cost-effectiveness.

Table 3.5. Conditions and contexts for adopting differing strategic approaches

Approach	When it is adopted	Sectors	Key Contingencies	Effects on international competitiveness
<i>Digital Transformation-led</i>	- Operational efficiency, speed, and cost reduction as primary goals - Digital tools central to strategy - Sustainability as secondary or incidental	Metalworking, Metal components	- Strong competitive pressures - Technological advancements availability - Customer demands for innovation and efficiency	Strengthened by operational efficiency and speed, improving cost-effectiveness and responsiveness in global markets
<i>Sustainability-led</i>	- Centrality of ecological and social goals - Regulatory or market demand emphasizing sustainability - Digital tools play a supporting role	Aesthetic material finishes, medical instruments	- Stringent environmental regulations - Need for brand differentiation - Stakeholder pressure for sustainability	Enhanced by meeting global sustainability standards, improving brand reputation, and aligning with customer expectations
<i>Parallel</i>	- Digital and sustainability efforts pursued independently - Separate market or regulatory pressures - Integration limited by resource constraints or fragmented organizational structures	Machinery engineering, industrial machinery	- Limited financial or organizational capacity for integration - Market demands for both sustainability and digitalization	Achieved incrementally by addressing specific market or regulatory demands for digital and sustainable practices without full synergy
<i>Integrated</i>	- Firms with solid leadership commitment and resource flexibility - Sustainability and digital transformation strategically interwoven	Precision components, machinery production	- Proactive leadership - Market demand for sustainable and technology-driven solutions - Advanced organizational structure and vision	Achieved through the synergistic benefits of digital transformation and sustainability, offering innovation, resilience, and enhanced international positioning

In contrast, the sustainability-led pathway prioritizes ecological and social objectives, with digitalization playing a supporting role in enhancing and monitoring these efforts. Here, the relationship between digitalization and sustainability is one of enhancement rather than dependence. Digital tools are utilized to track emissions, optimize resource utilization, and enhance reporting accuracy – key requirements for achieving sustainability goals and

complying with environmental regulations (Ciulli and Kolk, 2023; Oghazi et al., 2024). This pathway is particularly effective in sectors where customers and regulators value eco-friendly and responsible business practices, enabling SMEs to strengthen competitiveness through environmental credibility and brand differentiation. Although motivated primarily by sustainability objectives, digital technologies can also support efficiency and quality while reducing resource consumption (Ferreira et al., 2023; Mustafa et al., 2024), enabling firms to meet international expectations without incurring significant costs associated with digital transformation. Sustainability is deeply embedded in the firm's DNA and is driven by a deliberate choice to align business operations with sustainability principles. The connection between digitalization and sustainability is contextually driven. Technology facilitates sustainability objectives, but it does not define the firm's overall competitive approach.

Similarly, the parallel approach reflects the reality that not all SMEs are able to fully align digital transformation with sustainability. In this pathway, these two strategies operate as separate entities, each targeting distinct demands. Digitalization focuses on operational needs, such as improving productivity, efficiency, and customer service (Ahi et al., 2022), while sustainability responds to regulatory requirements and stakeholder expectations (Díaz-Chao et al., 2021; Luo and Zahra, 2023; Mustafa et al., 2024). Although not convergent, both strategies positively contribute to international competitiveness and positioning. The parallel approach is a pragmatic solution for SMEs facing operational, regulatory, and market pressures but lacking the resources or flexibility for full integration. Over time, with increased experience, they may develop resource availability or shift toward integrated planning, leading to an evolution into a more cohesive strategy. This pathway thus represents an adaptive stage where SMEs progressively address multiple pressures without compromising their immediate competitiveness.

Finally, the integrated approach represents a more comprehensive stage of digital-sustainability alignment. Integration here is primarily strategic in nature. Digital transformation and sustainability are deliberately framed as a single, joint response to international competitive pressures rather than as separate or sequential priorities. The relationship between the two strategies is symbiotic. Digitalization enhances transparency, energy efficiency, and resource management, while sustainability drives digital innovation, reduces the firm's ecological footprint, and meets the growing demand for responsible business practices. As a result, integration subsequently materializes in coordinated implementation processes and the development of organizational competences that span digital, operational, and sustainability domains. This approach proves particularly advantageous in markets where technological sophistication and environmental accountability are valued, positioning SMEs as resilient and future-oriented suppliers (Broccardo et al., 2023). However, it may not be the most feasible pathway for all, especially for SMEs facing resource constraints (Denicolai et al., 2021; Pham and Vu, 2024) or active in markets where a simpler approach may suffice. Its successful implementation requires strong leadership commitment, resource flexibility, and organizational capacity.

Our analysis aims to advance the theoretical understanding of digital transformation and sustainability by showing that each pathway provides a valid, context-dependent route to international competitiveness. Through a contingency-based lens (Donaldson, 2001; Lawrence and Lorsch, 1967), the study reveals that the connection between the two strategies can range from indirect, as in the digital transformation-led pathway, to supportive, in sustainability-led approaches, to complementary, in parallel approaches, or strategically integrative, within integrated pathways, depending on the firm's internal and external fit (Van de Ven et al., 2013). This multiplicity of configurations underlines SMEs' adaptability in strategically aligning resources and objectives to fit the demands of international markets.

6. Conclusions

The study explores how SMEs integrate digital transformation and sustainability to achieve international competitiveness. The analysis identifies four distinct yet interrelated pathways, showing that each represents a context-specific response to external pressures, internal resources, and strategic priorities. By examining these configurations, the research contributes to IB literature by demonstrating that there is no single, optimal route toward international competitiveness. Rather, SMEs strategically adapt their digital and sustainable initiatives to fit their environmental, market, and organizational conditions. These findings extend the contingency theory to the domain of twin transitions (Tabares et al., 2025), offering an empirically grounded understanding of how digitalization and sustainability interact to shape international competitiveness, while providing relevant insights to managers and policymakers.

6.1. Theoretical implications

The research provides several contributions to IB research. First, it demonstrates that SMEs pursue multiple, context-specific pathways depending on external pressures, internal resources, and strategic priorities (Van de Ven et al., 2013). This supports a contingent view of strategic alignment, suggesting that digital transformation and sustainability do not require convergence to enhance international competitiveness. Instead, each pathway offers contextually specific routes, highlighting that digitalization and sustainability are adaptable rather than inherently synergistic. Their integration depends on industry, market conditions, and firm-specific constraints, demonstrating the contextual nature of their integration in IB contexts.

Second, the findings extend the contingency theory by illustrating how SMEs' pathways reflect adaptive strategies to align with dynamic external environments (Maletič et al., 2018; Tiwari et al., 2024). The study broadens its scope by focusing on the dual strategic goals of digital transformation and sustainability, demonstrating that SMEs can derive a competitive

advantage by adopting distinct, sector-specific strategies that still enable international competitiveness.

Third, the research emphasized the role of adaptive learning and strategic evolution as pathways evolve from one model to another (e.g., from parallel to integrated approaches). SMEs often become aware of potential digital-sustainability synergies over time, adjusting their pathways in response to performance outcomes, competitive pressures, and stakeholder demands (Mustafa et al., 2024). This points to the role of adaptability in shaping integrated strategies as organizational and environmental complexities evolve (Van de Ven et al., 2013).

Finally, the study shows the influence of market-specific contingencies – such as regulatory pressures, customer expectations, and competitive intensity (Maletič et al., 2018; Tiwari et al., 2024) – on SMEs' pathway selection. This has implications for IB research regarding how SMEs in diverse institutional and competitive contexts prioritize or combine their digital and sustainable activities differently.

6.2. Managerial implications

The findings have practical value for managers seeking to enhance the international competitiveness of SMEs through digitalization and sustainability. For managers, the diversity of pathways offers strategic flexibility. Firms should assess their industry's specific demands, available internal resources, and stakeholder expectations to identify the most viable configuration. In highly regulated sectors, sustainability-led pathways may offer stronger differentiation, while in technology-intensive industries, digital transformation can be the key driver of competitiveness. Managers should also view the chosen pathway not merely as an operational decision but as a means to shape brand identity and long-term positioning in international markets.

For policymakers, the results highlight the importance of supporting SMEs' dual transformation through targeted incentives and enabling conditions. Policies promoting access to digital infrastructure, green technologies, and international sustainability certifications can encourage firms to move toward more integrated models. Policy frameworks that recognize the heterogeneity of SMEs' pathways can thus enhance both national innovation capacity and sustainable internationalization.

6.3. Limitations and Future Research

While providing rich insights into the strategic pathways adopted by Italian SMEs to achieve international competitiveness, this qualitative study presents several limitations. First, its focus on a specific geographic and industry context limits the generalizability of findings (Poulis et al., 2013). Future research could broaden this framework by examining SMEs across countries and industries to assess how external pressures and organizational factors influence strategic alignment.

Second, the qualitative, multiple-case study design (Yin, 2016) limits the ability to measure the direct impact of each pathway on financial and operational performance. Future studies could employ quantitative or mixed-method approaches to test the impact of each pathway on international firm performance.

Third, while the identified approaches reflect distinct strategic configurations, they may not capture the full range of dynamic forces shaping firms' evolution. Future research could investigate the mediating and moderating variables – such as technological change, institutional pressure, or managerial cognition – that influence how digital transformation and sustainability affect SMEs' international competitiveness.

Finally, longitudinal studies would provide valuable insights into how SMEs adjust their pathways over time to maintain their internal and external organizational fit (Van de Ven et al.,

2013). Therefore, future studies could focus on investigating how managerial awareness and perception evolve, shaping the recognition of digital-sustainability synergies and influencing firms' strategic shifts.

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Essay 3

INDUSTRY 4.0 AND THE PERFORMANCE OF EXPORTING FIRMS: THE MEDIATING ROLE OF SUSTAINABILITY PRACTICES

Abstract

Although the literature has analyzed the impact of Industry 4.0 and sustainability on performance indicators, their combined impact remains largely unexplored. This article investigates the link between Industry 4.0, sustainability practices, and the international performance of exporting companies. To test these relationships, we apply multivariate linear regressions and mediation analysis on survey data collected from 239 manufacturing export companies. Our results reveal that both Industry 4.0 and sustainability practices significantly enhance the international performance of exporting firms. Additionally, sustainability practices partially mediate the impact of Industry 4.0 technologies on both international financial and operational performance. Our research advances the understanding of how the combination of Industry 4.0 and sustainability practices influences the international performance of companies in a context where the twin transitions are promoted as central to the sustainable future of society. Practical implications for managers and policymakers are discussed.

Keywords: *Industry 4.0; Sustainability practices; International Performance; Exporting companies; Manufacturing*

1. Introduction

In the past decade, digital transformation and sustainability imperatives have increasingly attracted the attention of international business (IB) scholars (Del Río Castro et al., 2021) and policymakers, in a context where the twin transitions are promoted as a key concept for sustainable development (Rehman et al., 2023). The fourth industrial revolution has brought a new paradigm in manufacturing, integrating the digital and physical worlds, with advanced Industry 4.0 technologies reshaping production systems, plants, factories, and organizations (Culot et al., 2020; Kagermann, 2015). Industry 4.0 encompasses a set of technologies that enable interconnection and integration of operations through cyber-physical systems and data-

processing technologies, allowing real-time information sharing and management, and improving the communication and coordination of operations in manufacturing (Dalenogare et al., 2018). Accordingly, IB scholars have identified Industry 4.0 technologies as endowments that might impact the international competitiveness of firms in international markets (Ghobakhloo et al., 2021; Luo & Zahra, 2023), making it possible to build more resilient operations (Srinivasan & Eden, 2021; Stoian et al., 2024), reduce costs, and enhance responsiveness to customers and regulatory demands (Kazemi et al., 2023). IB research has suggested that Industry 4.0 may reshape firms' international relationships with suppliers and customers, localization decisions (Strange & Zucchella, 2017), value creation and capture mechanisms (Lee et al., 2023; Sauter et al., 2015; Wee et al., 2016), market selection (Ahi et al., 2022), and global value chain configurations (Alcácer et al., 2016; Porter & Heppelmann, 2015). Existing studies have mostly investigated the impacts of single technologies (Ahi et al., 2022), such as big data analytics (BDA) (Yadegaridehkordi et al., 2018), or 3D printing (Hannibal & Knight, 2018), whereas major impacts are expected when these technologies are adopted in an integrated and synergic manner (e.g., Bortoluzzi et al., 2022; Szász et al., 2020). Moreover, research treating Industry 4.0 as a comprehensive concept including multiple technologies has mostly focused on its internationalization-related outcomes, such as reshoring (Dachs et al., 2019), value creation and capture of international subsidiaries (Lee et al., 2023), and value chain reconfigurations (Alcácer et al., 2016; Strange & Zucchella, 2017) rather than on international performance.

Although requiring considerable initial capital investment, extant studies generally agree on Industry 4.0's positive impacts on operational efficiency, productivity, and performance of manufacturing firms (e.g., Bettiol et al., 2022). Industry 4.0 often leads to cost reductions and better allocation of resources in operational processes, thus positively impacting environmental and social sustainability performance indicators (Broccardo et al., 2023).

Meanwhile, the growing consumer demand for environmentally and socially responsible products and services, regulatory pressures, and the increased stakeholder interest in environmental and social sustainability put companies under pressure to adopt sustainable practices (Van Tulder et al., 2021). For firms seeking to compete internationally, environmental and social initiatives are no longer peripheral but are now recognized as key operational strategies (Gupta & Gupta, 2020; Rao & Holt, 2005). Still, the link between sustainability practices and firm performance remains inconclusive and at times contradictory (Maury, 2022), raising the need to clarify whether and when being sustainable pays off (Park, 2023). Notably, a specific gap persists in understanding whether sustainability practices influence international performance in companies operating in diverse international environments (Gupta & Gupta, 2020; Li et al., 2017).

Besides, existing IB research has not yet considered the joint role of Industry 4.0 and sustainability practices at the organizational level for the competitiveness of exporting companies (Denicolai et al., 2021). Initial evidence suggests that sustainability practices can mediate the relationship between Industry 4.0 and specific performance indicators, such as sustainability ones (e.g., Yavuz et al., 2023), even though this aspect has not been analyzed in the context of exporting companies. In fact, although both might be critical for international competitiveness, investing simultaneously in the adoption of Industry 4.0 and sustainability practices might also lead to conflicts in resource allocation (Ardito, 2023; Valero-Gil et al., 2024), especially when pursuing international expansion (Denicolai et al., 2021). Prior research has examined the separate effects of Industry 4.0 and sustainability initiatives on firm outcomes; however, little is known about how these dimensions interact to shape international performance. To address this gap, our study anchors on the resource-based view (Barney, 1991; Penrose, 1959; Peteraf, 1993) to investigate the relations between Industry 4.0, sustainability

practices as strategic resources, and the companies' international performance, analyzing survey data from 239 Italian exporting manufacturers.

Our contributions to IB are threefold. First, we extend prior findings on the Industry 4.0-performance relationship by empirically testing the positive impact of advanced technologies on firms' international performance, enriching the scarce IB literature on Industry 4.0 that is currently focused on single technologies (Ahi et al., 2022) or specific internationalization-outcomes (Dachs et al., 2019; Lee et al., 2023) rather than international performance (Mosconi, 2015). Second, we clarify the relationship between sustainability practices and international performance, complementing prior studies that provided contrasting evidence on the sustainability-performance relation (Rahi et al., 2022), while also shifting the focus from sustainability performance (Broccardo et al., 2023) to sustainability practices at the organizational level (Denicolai et al., 2021). Lastly, we empirically investigate the interlinks between Industry 4.0, sustainability practices at the organizational level, and the international performance of companies, extending the knowledge in an unexplored field.

2. Hypotheses Development

2.1. Industry 4.0 and International Performance

Technology, which ranges from R&D to information technology, has always represented a critical resource-endowment for the competitive advantage of manufacturing companies across the different industrial revolutions (Barney, 1991; Gustavsson et al., 1999; Peteraf, 1993). However, compared to previous technologies like automation and the internet, the technological advances labelled under Industry 4.0 represent a game-changer for several reasons. Industry 4.0 includes technologies like the Internet of Things (IoT), BDA, cloud computing, cybersecurity, 3D printing, data and system integration within the company and across its borders (namely, vertical and horizontal integration), simulation systems, augmented and virtual reality, advanced and collaborative robotics, and blockchain (Culot et al., 2020). Despite this variety,

previous studies have suggested that, in addition to the single technologies' impacts on performance (e.g., Al-Surmi et al., 2022; Strange & Zucchella, 2017), major effects can be derived from cumulative adoption and strategic alignment of multiple Industry 4.0 technologies (e.g., Bortoluzzi et al., 2022; Müller et al., 2021). Industry 4.0 technologies, like intelligent automation and robotics in production and logistics, interconnected machines and plants through cyber-physical systems embedded in plants and factories, optimize strategic and production planning, reduce production costs, waste, and lead times, and improve productivity and operational efficiency (Estensoro et al., 2022; Tortorella et al., 2019) and environmental performance (Broccardo et al., 2023). Moreover, when integrated in operations and logistics, they enhance flexibility and customization levels, favoring an improved alignment between supply and demand (Al-Surmi et al., 2022; Dachs et al., 2019; Müller et al., 2021). Simulation systems, 3D printing, and augmented reality expand possibilities for designing, prototyping, and production to create on-demand customized products or simply offer additional services to customers (e.g., Hannibal & Knight, 2018). Real-time data sharing and analytics enabled by IoT, BDA, blockchain and machine learning can support decision making, increase transparency and traceability, and better align information and financial and operational flows within the organization and across its local and global supply chains (Luo & Zahra, 2023; Romanello & Veglio, 2022; Strange & Zucchella, 2017), with positive returns upstream (e.g., further waste and cost reduction) and downstream (e.g. improved service level and customer orientation) (Bettioli et al., 2022; Bortoluzzi et al., 2022). In international markets, ICT and digital platforms can further reduce entry barriers and strengthen connectivity, enabling firms to expand more rapidly and with fewer resources (Brouthers et al., 2016).

As a second argument, Industry 4.0. requires substantial capital investment, specific digital capabilities that might be difficult to develop internally or acquire in the labor market, while change management issues might arise during the implementation process (Romanello &

Veglio, 2022). For these reasons, the profitability implications of Industry 4.0 adoption remain mixed. Nonetheless, companies that have adopted a greater number of Industry 4.0 technologies might have overcome this initial digitalization paradox (Xu et al., 2024) and developed or acquired the necessary digital skills to carefully select and integrate the most suitable technologies within the company's strategy and structure. Building on evidence not specific to international companies, we suggest that the implications outlined above can also enhance the competitiveness of firms operating in global markets, not only by increasing cost efficiency, flexibility, and customization, but also by enabling new ways to profile customers, screen, select and analyze foreign markets, identify international opportunities, and meet the fast-changing demand. Thus, we hypothesize that Industry 4.0 adoption within the organization represents a technology-based advantage that positively impacts the international performance of exporting companies.

***Hypothesis 1:** Industry 4.0 technologies are positively related to the international performance of firms.*

2.2. Sustainability Practices and International Performance

The integration of sustainability into core business strategies has increasingly become a global imperative, driven by stringent environmental regulations, rising customer concerns for ethical practices, and shifting societal expectations favoring businesses' activities that safeguard resources for future generations (Hermundsdottir & Aspelund, 2022). Aligning international and sustainability strategies by embedding social and environmental considerations into decision-making (Choi & Lee, 2017; Van Tulder et al., 2021) and organizational practices (Denicolai et al., 2021) becomes central to the long-term competitiveness of exporting firms (Van Tulder et al., 2021). Sustainability practices at the organizational level can act as sources of competitive advantage (Maury, 2022; Park, 2023; Taticchi et al., 2015), fostering operational

efficiency, innovation, and knowledge exchange. Environmental practices, such as green supply chain management and lean production, favor cost savings, reduce waste, and improve productivity, while minimizing environmental harm (Rao & Holt, 2005). The resulting “lean and green” effect makes firms more competitive in international markets by lowering production costs and improving responsiveness (Hermundsdottir & Aspelund, 2022). Beyond these, companies implementing Corporate Social Responsibility (CSR) practices pursue deeper resource and value creation, moving beyond the mere reduction of negative impacts. CSR enhances performance through improved efficiency, innovation, product differentiation, reputation, and risk reduction (Al-Shammari et al., 2022; Maury, 2022). Similarly, practices aimed at developing environmentally friendly products stimulate explorative innovation (e.g., developing new products for new markets) and exploitative innovation (e.g., refining existing offerings to maintain competitiveness), thereby strengthening product and brand differentiation (Costa et al., 2015; Ullah et al., 2021). Environmentally and socially responsible attributes can also match global consumer preferences (Boehe & Cruz, 2010; Park, 2023), enhancing customer loyalty and export performance (Gupta & Gupta, 2020; Ullah et al., 2021). Engaging in sustainability practices builds trust and corporate image of firms, which is key to attracting international customers, investors, partners, and skilled employees (Li et al., 2017; Rao & Holt, 2005). It also contributes to reducing the risks of reputational damage, regulatory sanctions, and supply chain disruptions (Maury, 2022). Social practices at the organizational level further contribute to competitiveness by favoring work-life balance, inclusivity, and intra-organizational knowledge-sharing, aspects that contribute to reduced employee turnover and increased happiness, creativity, and innovativeness in the workplace (Ravina-Ripoll et al., 2019).

Altogether, sustainability practices can strengthen productivity, financial results, corporate and brand reputation, and trust levels in international markets (Guo et al., 2024).

While most prior research has examined sustainability performance as an outcome, evidence from emerging markets indicates that sustainable management practices also improve export performance (Palma et al., 2018) and financial and market outcomes (Gupta & Gupta, 2020). Building on this, we argue that sustainability practices play a critical role in enhancing the international performance of firms by fostering innovation, efficiency, legitimacy, risk reduction, and responsiveness to growing demand for green products and responsible governance (e.g., Broccardo et al., 2023; Guo et al., 2024). Thus, we hypothesize:

Hypothesis 2: *Sustainability practices are positively related to the international performance of firms.*

2.3. Industry 4.0, International Performance, and the Role of Sustainability Practices

The implementation of Industry 4.0 can lead to major changes in production systems and structures, task and business function organization and coordination mechanisms, supply chain management, and strategic decision processes (Díaz-Chao et al., 2021). The synergies between Industry 4.0 and sustainability practices have been increasingly emphasized in academic literature, with scholars addressing the integration of advanced digital technologies as a catalyst for systemic sustainability transitions, within the logic of the so-called “twin transitions” (e.g., Rehman et al., 2023). The adoption of Industry 4.0 technologies can facilitate sustainable practices, such as circular economy principles, sustainable design and production, green procurement, green cloud computing, energy monitoring, and transparent and traceable supply chain processes (Beltrami et al., 2021; Harikannan et al., 2025). In particular, the interaction between Industry 4.0 technologies and sustainable practices can yield synergistic win-win outcomes by enabling more efficient resource use to achieve strategic and sustainability goals (Díaz-Chao et al., 2021; Porter & Linde, 1995).

Additionally, Industry 4.0 technologies act as enablers of sustainability practices that, in turn, unlock new performance outcomes in international markets (Guo et al., 2024). By reconfiguring internal and external capabilities towards more sustainable operations, they support circular economy practices like reuse or remanufacturing (Kamble & Gunasekaran, 2023). Technologies like IoT, BDA, cloud platforms and blockchain allow real-time tracking of materials and components, support measurable, auditable, and transparent processes across supply chain, and traceability throughout product lifecycles (Khan et al., 2021; Lopes de Sousa Jabbour et al., 2018), also enabling waste reduction, predictive maintenance, and circular resource flows (Ardito, 2023; Chauhan et al., 2021; Lopes de Sousa Jabbour et al., 2018). Industry 4.0 also improves performance measurement by facilitating the detection of inefficiencies and enhancing financial and sustainability reporting (Beltrami et al., 2021). Additionally, it increases visibility within the organization and across its borders, allowing data-sharing with suppliers and customers, improving decision-making processes, and facilitating sustainable purchasing (Ghadimi et al., 2019; Beltrami et al., 2021). It can also favor a virtual proximity with customer preferences thanks to IoT and data analytics performed on internal or open data, which can translate into product or process innovations and eco-design practices that align with the growing global demand for green products. Consequently, selling green products or services may also grant certifications positively perceived in international markets, improving access to international opportunities (Guo et al., 2024).

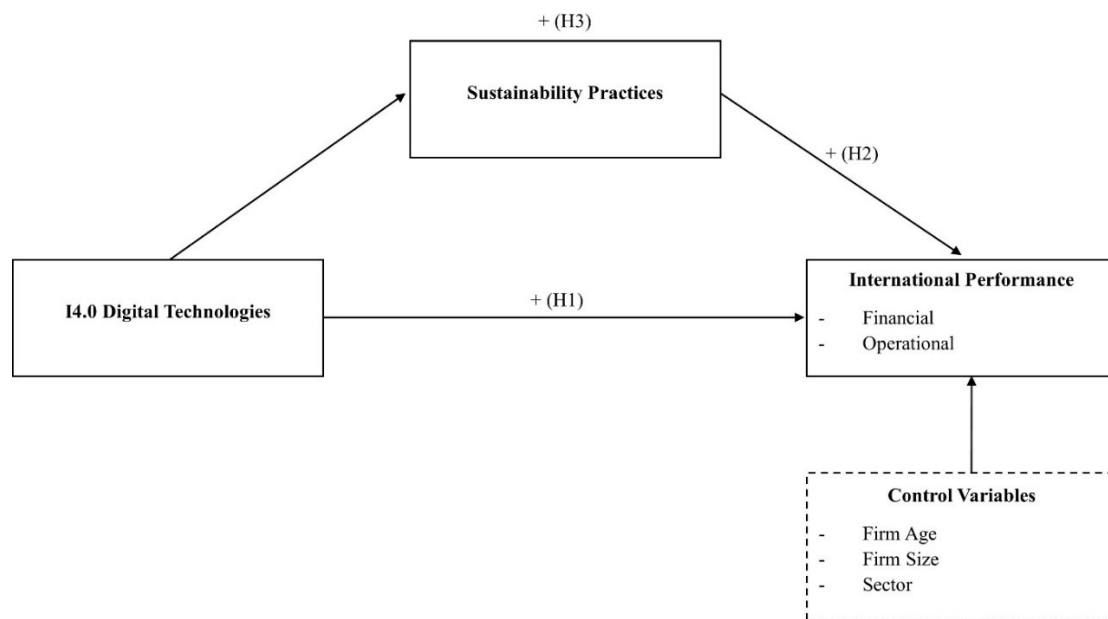
Industry 4.0 technologies, like advanced robotics in operations and logistics, interconnected machines in the factories that allow remote supervision and management, can also favor social sustainability practices by supporting gender and work-life balance within the organization and across its supply chain (Harikannan et al., 2025; Romanello & Veglio, 2022). While there is a broad and open debate on the dark side of Industry 4.0 and artificial intelligence, particularly around long-term job displacements (Bag & Pretorius, 2022), evidence has also

shown that adopting Industry 4.0 can support remote working, increase flexibility, broaden tasks and supervisory roles, and facilitate knowledge sharing through data exchanges (Romanello & Veglio, 2022).

As a further argument underlying our hypothesis, we argue that companies jointly implementing Industry 4.0 and sustainability practices must have a multi-objective profile (Valero-Gil et al., 2024), having developed the capabilities needed to navigate turbulent and competitive environments while pursuing organizational goals. Prior studies show that circular economy and sustainable operations (or manufacturing) practices fully mediate the effect of Industry 4.0 on sustainable performance (Harikannan et al., 2025; Kamble & Gunasekaran, 2023) and sustainability outcomes (Yavuz et al., 2023). Similarly, evidence suggests that digitalization strengthens profitability when sustainability performance is integrated (Broccardo et al., 2023). Building on this, we propose that the integration of Industry 4.0 and sustainability practices extends beyond sustainability outcomes to also enhance the international financial and operational performance of exporting firms. This occurs because such integration creates synergies and complementarities in input utilization, while also enabling mechanisms that generate greater value (Valero-Gil et al., 2024), ultimately improving competitiveness in international markets. Industry 4.0 further enhances firms' ability to adopt and scale sustainable practices, which in turn supports improved international performance. Thus, we hypothesize the following:

Hypothesis 3: *The relationship between the Industry 4.0 technologies and the international performance of firms is mediated by sustainability practices.*

Figure 4.1 presents the hypotheses within a unified conceptual framework.

Figure 4.1. Conceptual Model of the Study

3. Methodology

3.1. Data Collection and Sample Characteristics

To empirically test our hypotheses, we conducted a survey using the Computer-Assisted Telephone Interviewing (CATI) methodology. The sample was drawn from a population of 3,532 firms in the fashion, furniture and wood, and mechanical engineering sectors, including plastics, machinery, and electronic equipment manufacturing, located in Northeastern Italy, each with turnover exceeding 5 million Euros in 2023.

These industries were selected as the focus of our study for two main reasons. First, they display a strong international orientation. Second, they represent some of the most established, innovation-driven sectors that significantly contribute to regional employment and industrial output (ISTAT, 2023). To align with the scope of our research, we focused on exporting companies, which are prevalent in the selected industries. To ensure methodological rigor, data collection was entrusted to a professional data collection firm. Prior to the survey, firms received a pre-notification email and a cover letter clarifying the voluntary nature of participation, guaranteeing anonymity, and explaining that the data would be used solely for academic research and dissemination purposes (Dillman, 2000; Podsakoff et al., 2012). The

survey was conducted as part of the iNEST project (www.consortioinest.it), an initiative promoting digital and sustainable transformation in strategic industrial sectors through collaboration between universities and firms.

The CATI method was chosen, given the questionnaire's complexity and length (Podsakoff et al., 2012). This approach helped improve content validity, as trained interviewers supported respondents in interpreting and answering the questions accurately (Bortoluzzi et al., 2022; Podsakoff et al., 2012).

We collected data in May and June 2025. A total of 305 firms completed the survey, yielding a response rate of 8.64%, consistent with benchmarks commonly observed in firm-level survey studies (Dillman, 2000). After removing non-exporting firms from our dataset, the final sample comprised 239 valid responses. A detailed breakdown of the sample characteristics is presented in Table 4.1.

Table 4.1. Sample Description

Characteristics	Mean	SD	Min	Max
Age	39.73	21.19	3.00	189.00
Turnover (Million of Euros)	21.61	38.22	5.00	350.48
Employees	75.53	107.95	3.00	780.00
Foreign sales on total sales (%)	38.56	28.25	1.00	99.00
Industry	N		%	
Wood and furniture	19		7.9	
Mechanical engineering	187		78.2	
Fashion	33		13.8	
Industry 4.0 technologies adoption	N		%	
Adopters	184		77.0	
Non adopters	55		23.0	
Industry 4.0 technologies	N		% of the total	
Robotics /Advanced automation	67		28.0	
Autonomous robots / Co-bots	63		26.4	
Additive manufacturing	26		10.9	
Simulation / Modelling	58		24.3	
IoT	21		8.8	
BDA	13		5.4	
Cloud computing	101		42.3	
AI / Machine Learning	25		10.5	
Cybersecurity	120		50.2	
AR / VR	9		3.8	
Blockchain	52		21.8	
Machine connectivity / Smart factory	88		36.8	

3.2. Questionnaire and Measures

The survey instrument was developed through a multi-step process to ensure conceptual clarity and empirical validity. First, the structure and content were informed by insights gathered from qualitative interviews with senior managers from firms located in the target industries (Gerschewski et al., 2015). In collaboration with a professional survey firm, we conducted a preliminary assessment to identify potential questionnaire-related issues in question wording, terminology, and layout. This was followed by a pre-test involving 30 manufacturing firms, which led to several refinements to improve comprehensibility and precision of specific items (Dillman, 2000).

The final questionnaire included 40 closed-ended questions across five thematic sections. The average completion time was approximately 20 minutes. Respondents held senior roles in the firm, including CEOs, sustainability and safety managers, production and quality managers, and business owners.

The analysis was developed based on a set of robust variables and constructs derived from established literature to capture the dynamics between Industry 4.0, sustainability practices, and firm performance. Table 4.2 provides a complete overview of the variables used in empirical analysis.

3.2.1. Dependent Variables

To evaluate firm international performance, we employed two distinct performance outcomes: international financial performance and international operational performance (Hult et al., 2008). International financial performance was measured as the firm's relative performance in international markets over the past five years, using previously tested constructs (Donbesuur et al., 2020; Gerschewski et al., 2015). Consistent with prior studies analyzing international performance (e.g., Gerschewski et al., 2015; Jantunen et al., 2008) we employed subjective

performance measures, which are commonly used in the literature and have been shown to correlate positively with objective indicators (Jantunen et al., 2008). Respondents were asked to self-assess performance compared to competitors on a five-point Likert scale, including items regarding the company's international market share, international sales volume, growth in international sales, and overall international financial results. The measure exhibited high internal consistency (Cronbach's $\alpha=0.81$).

International operational performance was assessed through seven strategic outcome indicators, based on Gerschewski et al. (2015). Respondents indicated their agreement on a five-point Likert scale regarding enhancements in international market share, product portfolio expansion, time to market reduction, success of new products, global reach, reputation, and gaining of foothold in international markets over the past five years (Cronbach's $\alpha=0.81$).

3.2.2. Independent Variables

Sustainability practices were measured using seven items adapted from Denicolai et al. (2021), Ferreira et al. (2023), and Valero-Gil et al. (2024). On a five-point Likert scale, respondents indicated the extent to which their firm implemented resource and energy-saving measures, circular economy practices, sustainable energy sources, environmentally friendly products, workplace conditions improvements for their employees, diversity, equality, and inclusion policies, and employee engagement practices. These items, reflecting environmental and social dimensions of sustainability, were integrated into a composite index, capturing a wide range of sustainability practices adopted by the firm. The construct demonstrated high internal consistency (Cronbach's $\alpha=0.85$).

Industry 4.0 technology adoption was operationalized by measuring the extent of digital transformation within the firm. Respondents reported the presence or absence (1=used, 0=not used) of twelve core Industry 4.0 technologies identified in prior literature (Culot et al., 2020;

Frank et al., 2019; Rüßmann et al., 2015). These included robotics and automation, additive manufacturing, IoT and smart sensors, BDA, artificial intelligence (AI), cloud computing, cybersecurity, simulation tools, augmented reality and virtual reality (AR/VR), blockchain, machine connectivity, and interconnectivity, autonomous systems, and smart factory applications. An aggregate Industry 4.0 index was constructed following the approach by Dachs et al. (2019). The objective of this measure was to capture the strategic breadth and sophistication of the firm's technological portfolio, addressing the heterogeneity in the use of these technologies. Consequently, each technology was weighed by the inverse of its relative frequency in the sample. This approach attributes greater weight to less adopted, more advanced technologies typically implemented by innovation-leading firms, while down-weighting mature and widely used technologies. This ensures that the index serves as a proxy for innovation leadership, distinguishing firms with the capacity to implement complex solutions from those that merely conform to baseline industry standards. The index was calculated using the following formula:

$$\begin{aligned} \text{Industry 4.0 index} = & \text{Robotics } (1 - 0.28) + \text{Autonomous Robots } (1 - 0.26) + \text{Additive} \\ & \text{Manufacturing } (1 - 0.11) + \text{Simulation } (1 - 0.24) + \text{IoT } (1 - 0.09) + \text{BDA } (1 - 0.05) + \\ & \text{Cloud } (1 - 0.42) + \text{AI } (1 - 0.11) + \text{Cybersecurity } (1 - 0.50) + \text{AR / VR } (1 - 0.04) + \\ & \text{Blockchain } (1 - 0.22) + \text{Smart Factory } (1 - 0.37) \end{aligned}$$

3.2.3. Control Variables

To ensure the adequacy of our models, we controlled several firm-level characteristics commonly associated with performance. Firm size was proxied using the natural logarithm of annual turnover (Jantunen et al., 2008). Firm age was similarly measured as the natural logarithm of the number of years since the firm's establishment (Bortoluzzi et al., 2022). Sectoral dummies were included to account for industry-specific dynamics and represented the

three manufacturing sectors in our sample – fashion, wood and furniture, and mechanical engineering. These sectors differ in technological intensity, product complexity, and market demands, which can significantly influence both the adoption of advanced practices and performance patterns.

Table 4.2. Key Variable Description

Variable Name	Definition	Measurement Scale
International Financial Performance	Composite index measuring the firm's international financial performance relative to competitors, including international market share (IFP1), international sales volume (IFP2), international sales growth (IFP3), and overall international performance (IFP4).	5-point Likert scale (1=Much worse, 5=Much better)
International Operational Performance	Composite index measuring perceived improvements over the past five years in the firm's international operations, including international market share (IOP1), new product/service introduction in international markets (IOP2), time to market (IOP3), success of new products in international markets (IOP4), enhanced presence in strategic markets (IOP5), reputation (IOP6), gaining foothold in international markets (IOP7)	5-point Likert scale (1=Strongly disagree, 5=Strongly Agree)
Sustainability Practices	Composite index measuring firm sustainability practices including resource and energy-saving measures (SP1), circular economy practices (SP2), sustainable energy resources (SP3), development of environmentally friendly products (SP4), workplace conditions improvements (SP5), diversity, equality and inclusion (SP6), employee engagement practices (SP7)	5-point Likert scale (1=Not Adopted, 5=Widely Adopted)
Industry 4.0 Technology Adoption	Adoption of (1) Robotics /Advanced automation, (2) Autonomous robots / Co-bots, (3) Additive manufacturing, (4) Simulation / Modelling, (5) IoT, (6) BDA, (7) Cloud computing, (8) AI / Machine Learning, (9) Cybersecurity, (10) AR / VR, (11) Blockchain, (12) Machine connectivity / Smart factory	Binary indicators (0=Not adopted, 1=Adopted); Weighted sum
Firm Size	Annual turnover in euros (2023)	Continuous variable (natural logarithm)
Firm Age	Number of years since the firm's founding	Continuous variable (natural logarithm)
Sector	Sector classification of the firm, captured using dummy variables (Fashion, Wood / Furniture, Mechanical engineering)	Dummy variable (1=Yes, 0=No for each sector)

3.3. Methods

To examine how firms' adoption of Industry 4.0 technology and sustainability practices influences their international performance, we employed multivariate linear regression analyses complemented by mediation analysis, using R (version 4.5.1). This allowed us to assess both direct effects of technology adoption and indirect effects transmitted through sustainability

practices. First, we estimated regression models to test the influence of Industry 4.0 technology adoption and sustainability practices on international performance outcomes. Then, we conducted a mediation analysis to examine whether the effect of Industry 4.0 technology adoption on international performance operates indirectly through firms' engagement in sustainability practices. This involved estimating a mediator model and corresponding outcome models, followed by nonparametric bootstrapping to assess the statistical significance of indirect effects. Mediation analysis was implemented via the *mediation* package in R.

To address common method bias inherent in self-reported survey data, we adopted procedural strategies recommended by Podsakoff et al. (2012). First, we introduced proximal and psychological separation between independent and dependent variables by organizing the questionnaire into distinct thematic sections, placing performance-related items approximately 30 questions apart from those measuring Industry 4.0 and sustainability practices. We also embedded independent variables within broader thematic content to mask the study's focus (Podsakoff et al., 2012), and conducted the survey through telephone interviews, preventing respondents from revisiting previous answers and thereby minimizing response priming. Finally, to enhance cognitive engagement and response accuracy, participants were informed that their input would contribute to practitioner-oriented insights, in line with Dillman's (2000) tailored design principles. These combined efforts ensured that the measurement context supported valid and unbiased responses, strengthening the credibility of our empirical findings.

4. Results

Table 4.3 reports the descriptive statistics and correlations for the key variables. Firm international financial and operational performance indicators are significantly and positively correlated with Industry 4.0 technology adoption index and sustainability practices. Firm size and firm age show weak and non-significant correlation with performance indicators, although

firm size exhibits a moderate positive correlation with sustainability practices. Sector dummies reveal some systematic patterns. In fact, belonging to the fashion sector is positively correlated with performance measures.

To test the hypotheses, four multiple linear regression models were estimated. Model 1 and Model 2 examine the effect of independent and control variables on international financial and operational performance. Model 3 and Model 4 additionally include the indirect effect of sustainable practices on the relationship between Industry 4.0 and international financial and operational performance. Non-parametric bootstrapping was used for estimation. Table 4.4 presents the results of multivariate regression models and mediation analysis.

Model 1 and Model 2 assess the effects of Industry 4.0 technology adoption and sustainability practices on international financial and operational performance, respectively. Results indicate that Industry 4.0 is positively and significantly associated with both international financial ($p < 0.001$) and operational performance ($p < 0.001$) of exporting companies, supporting *Hypothesis 1*. Additionally, Model 1 and Model 2 results show that sustainability practices have a positive and statistically significant impact on international financial ($p < 0.001$) and operational performance ($p < 0.001$), suggesting that companies adopting environmentally and socially responsible measures perform significantly better in international markets. Thus, *Hypothesis 2* is supported. Among the control variables, firm size and firm age have no statistically significant effects. Sectoral effects show that fashion firms significantly outperform the reference group in both financial ($p < 0.001$) and operational performance ($p < 0.001$), while mechanical engineering firms show higher financial performance only ($p < 0.001$). These differences reflect greater international orientation in these sectors. The adjusted R-squared of Model 1 and Model 2 are 0.24 and 0.27, respectively, confirming the accuracy of model estimation.

Table 4.3. Pearson Correlation Matrix

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) International Financial Performance	2.96	0.90	1								
(2) International Operational Performance	3.07	0.80	0.8**	1							
(3) Sustainability Practices	3.08	0.92	0.35**	0.43**	1						
(4) Industry 4.0 Technology Adoption	1.84	1.86	0.36**	0.30**	0.29**	1					
(5) Firm Size	16.37	0.86	0.07	-0.01	0.18**	0.10	1				
(6) Firm Age	3.54	0.56	0.01	-0.01	-0.03	0.13	-0.27**	1			
(7) Sector: Wood and Furniture Dummy	0.08	0.27	-0.21**	-0.06	0.13*	-0.13*	-0.03	0.05	1		
(8) Sector: Mechanical Engineering Dummy	0.78	0.41	-0.02	-0.14*	-0.24**	0.03	-0.49**	0.08	-0.56**	1	
(9) Sector: Fashion Dummy	0.14	0.35	0.19**	0.22**	0.18**	0.07	0.56**	-0.13*	-0.12	-0.76**	1

239 observations; Significance levels: ** $p < 0.01$, * $p < 0.05$ (two-tailed test)

Table 4.2. Multivariate Regression Models

	Model 1 (International Financial Performance)	Model 2 (International Operational Performance)	Model 3 (International Financial Performance)	Model 4 (International Operational Performance)
Intercept	2.99 (1.39; p = 0.055)	7.48 (1.22; p = 0.000)	2.99 (1.39; p = 0.055)	7.48 (1.22; p = 0.000)
<i>Independent variables</i>				
Industry 4.0 Technology Adoption	0.25 (0.03; p = 0.000)	0.20 (0.03; p = 0.001)	0.25 (0.03; p = 0.000)	0.20 (0.03; p = 0.001)
Sustainability Practices	0.30 (0.06; p = 0.000)	0.37 (0.05, p = 0.000)	0.30 (0.06; p = 0.000)	0.37 (0.05, p = 0.000)
<i>Control variables</i>				
Firm Size	-0.08 (0.08; p = 0.241)	-0.27 (0.07; p = 0.000)	-0.08 (0.08; p = 0.241)	-0.27 (0.07; p = 0.000)
Firm Age	-0.01 (0.10; p = 0.856)	-0.05 (0.08; p = 0.356)	-0.01 (0.10; p = 0.856)	-0.05 (0.08; p = 0.356)
Sector: Mechanical Engineering Dummy	0.31 (0.20; p = 0.001)	0.06 (0.17; p = 0.487)	0.31 (0.20; p = 0.001)	0.06 (0.17; p = 0.487)
Sector: Fashion Dummy	0.39 (0.24; p = 0.000)	0.33 (0.21; p = 0.000)	0.39 (0.24; p = 0.000)	0.33 (0.21; p = 0.000)
<i>Indirect Effects</i>				
Industry 4.0 Technology Adoption			0.09 (0.01; p = 0.000)	0.11 (0.01; p = 0.000)
<i>Model Fit</i>				
Adjusted R ²	0.24	0.27	0.24	0.27
Max VIF	1.61	1.61	1.61	1.61

The dependent variable for each model is indicated in the first line.

Reported estimates are standardized.

Unstandardized standard errors and p-values in parentheses.

Significance levels: *** p < 0.001, ** p < 0.01, * p < 0.05, † p < 0.1

Reference category for sector dummies: Wood and furniture

N = 239

Model 3 and Model 4 indicate that sustainability practices have a positive relationship with Industry 4.0 adoption and international financial and operational performance. The 99% confidence interval confirms that sustainable practices significantly enhance the effects of Industry 4.0 adoption on international financial and operational performance indicators, thus supporting *Hypothesis 3*. Table 4.5 presents the results of the indirect effects and reports the model's goodness of fit.

Table 4.5. Summary of Indirect Effect and Model Fit

Effect	Indirect Effect	95% CI
Industry 4.0 Technology Adoption → Sustainability Practices → International Financial Performance	0.089	(0.042 - 0.154)
Industry 4.0 Technology Adoption → Sustainability Practices → International Operational Performance	0.112	(0.059 - 0.184)
Standardized coefficient of indirect effect.		
N = 239		

Model robustness was tested through adjusted R-squared. All Variance Inflation Factors (VIF) indicated no multicollinearity. In fact, all the VIF scores were below the standard thresholds ($VIF < 2.5$), supporting the stability of the coefficient estimates (Allison, 1999). The results of Harman's single-factor test indicated that common method bias was not a concern, as several factors emerged, and the variance was not predominantly accounted for by the first factor (Podsakoff et al., 2012). In fact, the test identified 3 factors, with the first explaining 33.55% of the total variance. As a further robustness check, we conducted additional analyses using an alternative international performance measure adapted from Al-Surmi et al. (2022) and Andersen and Foss (2005), as well as an alternative specification of Industry 4.0 adoption based on the technology breadth index computed as a simple sum of dichotomic variables measuring the adoption of each technology, adapted from Bortoluzzi et al. (2022). In all cases, the results remained consistent, reinforcing the validity of the original models.

5. Discussion

Our research goal was to investigate how the adoption of Industry 4.0 technologies and the implementation of sustainability practices influence the international performance of exporting firms, and whether these two dimensions reinforce one another. The findings point to a consistent pattern – both digital transformation and sustainability initiatives strengthen companies' ability to compete abroad, with sustainability reinforcing the positive effect of Industry 4.0 on international performance.

The findings show that Industry 4.0 technology adoption positively contributes to companies' international financial performance, suggesting that a higher adoption of Industry 4.0 technologies leads to positive financial returns for exporting firms. This supports the idea that companies with a greater endowment of advanced technologies develop the necessary capabilities to overcome the digital paradox (Bettiol et al., 2022), align technologies with strategic goals, and capitalize on the initial investment required to implement these technologies. Additionally, we find a positive correlation for the international operational performance, in line with prior studies showing that Industry 4.0 leads to improvements in productivity (Bettiol et al., 2022; Frank et al., 2019; Szász et al., 2020), strategic, financial, and sustainability performance (Bettiol et al., 2022; Bortoluzzi et al., 2022; Broccardo et al., 2023; Frank et al., 2019; Szász et al., 2020), critical for firms facing volatile demand, global competition, and regulatory complexity. Our results complement and extend previous studies, showing that Industry 4.0 adoption represents a pathway for firms to enhance their international performance indicators, both financial and operational ones.

Equally important is the role of sustainability practices. Companies that embed environmental and social responsibility into their day-to-day activities can achieve superior international outcomes, suggesting that such practices represent a form of strategic differentiation (Hermundsdottir & Aspelund, 2022). In international markets, where expectations of green and responsible business conduct are rising, sustainability strengthens firms' legitimacy, improves relationships with stakeholders, and fosters product and process innovation (Hermundsdottir & Aspelund, 2022; Maury, 2022). Our study complements and enlarges prior IB research showing that sustainability practices are both ethically desirable and economically and strategically rewarding for exporters.

The most significant insight of our study, however, lies in the interplay between Industry 4.0 and sustainability, and their impact on international performance. The evidence confirms

the mediating role of sustainability practices in the relationship between Industry 4.0 adoption and international performance, suggesting that greater endowment of Industry 4.0 technologies favors the implementation of sustainable practices within the organization and across supply chains (Beltrami et al., 2021; Broccardo et al., 2023; Rejeb et al., 2022). These technologies not only improve efficiency and effectiveness in resource allocation, more related to environmental aspects, but also have broader social implications, such as supporting work-life balance and enabling changes in tasks and roles through the adoption of advanced technologies such as data sharing and integration, cloud computing systems, and BDA (Beltrami et al., 2021). As shown by Lee et al. (2023), Industry 4.0 positively impacts firms' value creation and capture, which form the foundation of competitive advantage. In our view, advanced levels of Industry 4.0 rely on organizational infrastructure and capabilities that support decision-making at all organizational levels (Beltrami et al., 2021). When combined with sustainable practices, this alignment optimizes resource allocation and strengthens companies' capacity to create, appropriate, and sustain value, strengthening their competitiveness in turbulent and highly competitive international markets. Thus, aligning technology with responsible environmental and social practices (Bag & Pretorius, 2022; Broccardo et al., 2023; Gunaratne et al., 2023; Touriki et al., 2021) enables the development of more sustainable business models (Inigo et al., 2017; Sinkovics et al., 2021).

Ultimately, our findings suggest that while the adoption of Industry 4.0 technologies enhances international performance, their contribution becomes more meaningful when channeled through sustainability practices. It is through the latter that technological investments unfold their full potential, turning Industry 4.0 adoption into broader value and offering firms a more distinctive and resilient basis for competing in international markets.

6. Conclusions

The digital revolution offers a unique opportunity to accelerate progress toward sustainable development (Dantas et al., 2021; Del Río Castro et al., 2021; George et al., 2021). Against this backdrop, our analysis shows that companies adopting both Industry 4.0 and sustainability practices achieve superior international financial and operational performance, as they are better equipped to face the twin transitions required to build a sustainable future (Rehman et al., 2023). Our work contributes to IB by providing initial empirical evidence on the interlinks between Industry 4.0, sustainability practices at the organizational level, and firms' international performance. Drawing on the resource-based view, we argue that both Industry 4.0 technologies and sustainability practices may constitute valuable, rare, inimitable, and non-substitutable resources that strengthen firms' international competitiveness (Estensoro et al., 2022; Yavuz et al., 2023).

Our work makes three main contributions to IB literature. First, building on prior studies on Industry 4.0 technologies and performance, our study empirically demonstrates that greater levels of Industry 4.0 technologies positively impact the international competitiveness of companies, thus responding to recent research calls (Mosconi, 2015; Strange & Zucchella, 2017). To the best of our knowledge, our study is the first to focus explicitly on the international performance of exporting companies, thus complementing and extending works investigating Industry 4.0 and sustainability in relation to productivity and sustainability performance indicators (e.g., Szász et al., 2020). It also enriches the limited IB literature on Industry 4.0, which has so far mainly focused on single technologies or specific internationalization outcomes such as localization decisions or value creation mechanisms of international subsidiaries (Ahi et al., 2022; Dachs et al., 2019; Lee et al., 2023).

Second, the study empirically demonstrates the positive effect of sustainability practices on the international performance of firms, contributing to the open debate on the sustainability-

performance relation, which has produced mixed results so far (Rahi et al., 2022). It further shifts the focus from sustainability performance (Broccardo et al., 2023) to sustainability practices at the organizational level (Denicolai et al., 2021), which represent a firm-level strategic factor relevant for the competitiveness of companies operating in international markets.

Lastly, our findings show the mediating effect that sustainable practices have on the Industry 4.0-international performance relation, extending the knowledge in an unexplored research field. Our analysis suggests that the synergic adoption of Industry 4.0 and sustainability practices is well perceived in international markets, as it increases the international competitiveness of companies. Besides, we argue that aligning greater endowments of Industry 4.0 and sustainable practices not only enables more efficient resource allocation and recombination (e.g. Verbeke & Kano, 2016), but also enhances decision-making processes through timely, accurate, and predictive data analytics (e.g. De Vos et al., 2025). This technological support can free human resources from routine tasks, allowing them to focus on more supervisory and upgraded activities.

We believe that our work represents a first step, showing that, in prospect, this strategic combination might lead to increased levels of creativity and innovativeness as expected under a real Industry 5.0 paradigm, where, in the presence of the highest levels of technology adoption, the real potential for progress and competitiveness will be based on the advanced collaboration between humans and machines (Adel, 2022). Still, empirical research is needed to understand whether, under which conditions, and how advanced technologies successfully support the twin transitions of companies.

This paper presents some limitations that are described below. First, the cross-sectional design limits causal inference. Longitudinal studies are needed to better capture the dynamic interplay between Industry 4.0 adoption, sustainability practices, and international performance

over time. Second, while our sample focuses on manufacturing firms in Northeastern Italy, results may not generalize to other regions or industries showing different technological readiness, institutional conditions, or sustainability pressures. Future research should therefore examine different geographical and sectoral contexts to validate and extend our findings. Lastly, future studies should investigate additional mediators and moderators, such as organizational culture, digital capabilities, or external institutional pressures, that might influence the relationship between Industry 4.0, sustainability practices, and international performance.

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CONCLUSIONS

1. Synthesis and Main Conclusion

In a global economy marked by accelerating technological disruption and intensifying sustainability pressures, global firms increasingly face the complex task of aligning digital transformation and environmental responsibility (Luo & Zahra, 2023). This dissertation advances the understanding of how digital transformation and sustainability jointly enhance firms' international competitiveness, with a particular focus on small and medium-sized enterprises (SMEs). By integrating insights from international business (IB), strategy, and sustainability research, it develops a comprehensive view of the digital-sustainability-internationalization nexus. The first essay consolidates fragmented literature, identifying key thematic clusters and highlighting the need for integrated frameworks. The second essay provides qualitative evidence of how SMEs adopt distinct strategic pathways – digital transformation-led, sustainability-led, parallel, and integrated – depending on contextual contingencies. The third essay provides quantitative confirmation that Industry 4.0 technologies and sustainability practices are complementary, with sustainability partially mediating the effect of digitalization on international performance.

Overall, the dissertation demonstrates that digital and sustainable transformation are synergistic rather than competing imperatives (Denicolai et al., 2021), and that their alignment can yield superior global outcomes (Broccardo et al., 2023; Guo et al., 2024). Building on these findings, the following sections elaborate on the dissertation's broader contribution and implications. Finally, avenues for future research are discussed, highlighting emerging questions and opportunities to deepen the understanding of digital sustainability integration in IB.

2. Theoretical Contributions

This dissertation makes a relevant theoretical contribution to IB literature by explaining how digital transformation and sustainability jointly shape firms' international competitiveness and performance. Moving beyond the isolated analysis of digitalization, sustainability, and internationalization, it offers a unified framework that accounts for the complexity (Eden & Nielsen, 2020) of these dynamic global imperatives (Matt et al., 2023). By combining conceptual synthesis, qualitative exploration, and quantitative validation, the research develops a comprehensive theoretical understanding of how firms – particularly SMEs – navigate the twin transitions of digital and sustainable transformation in global contexts. Three overarching theoretical contributions emerge from this integration.

First, the dissertation establishes a conceptual foundation for the digital-sustainability-internationalization nexus, providing coherence to a fragmented and under-theorized field (Ocelík et al., 2023). Through the systematic literature review, it was established that existing studies have largely examined dyadic relationships but have not extensively theorized how the three domains interact simultaneously. The dissertation advances IB theory by positioning internationalization not as a passive setting but as an active mechanism that shapes and is shaped by digital and sustainability transformations. This reframing introduces the idea of mutual embeddedness between technological and sustainability imperatives and IB (Luo & Zahra, 2023). It conceptualizes firms' international operations as dependent on their capacity to adopt or align these two transformations within distinct institutional, industrial, and market environments, offering a more holistic understanding of how firms manage multiple forms of transformation across borders.

Second, the dissertation contributes to theory by articulating a contingent and evolutionary view of strategic alignment between digitalization and sustainability. The qualitative findings demonstrate that digital and sustainable transformations do not necessarily

converge in a linear or uniform manner. Instead, firms exhibit distinct strategic pathways reflecting context-specific combinations of resources, capabilities, and environmental pressures. This reconceptualization extends contingency theory by emphasizing that strategic fit in the digital-sustainability nexus is not static but adaptive (Maletič et al., 2018; Tiwari et al., 2024). Firms continuously adjust their configurations in response to learning, performance feedback, and stakeholder expectations, gradually moving toward greater alignment as synergies become more apparent over time. The idea of a pathway evolution introduced here contributes a dynamic, process-oriented view of how strategic fit develops (Van de Ven et al., 2013). This approach recognizes that competitive advantage arises not only from achieving fit at a given moment but from the ability to reconfigure digital and sustainability resources as external conditions change across the international context.

Third, the dissertation advances theoretical understanding by demonstrating the complementarity of digital and sustainability capabilities as strategic resources that jointly underpin international performance. Drawing on the resource-based view (RBV) (Barney, 1991; Peteraf, 1993) and validated through quantitative analysis, the research identifies sustainability practices as a mediating mechanism through which Industry 4.0 technologies enhance international outcomes. These empirical insights provide theoretical grounding for the proposition that digital transformation yields superior results when embedded with sustainability-oriented practices (Broccardo et al., 2023). In doing so, the dissertation extends the RBV by shifting attention from isolated resources to resource configurations – bundles of technologies and sustainability activities that interact in a synergistic manner. This understanding redefines how competitive advantage is conceptualized in IB – as the product of interrelated resources.

Taken together, these contributions propose an integrative theoretical model of dual transformation in IB, one that links conceptual structure, contextual variation, and capability

interaction. This model explains how firms create and sustain international competitiveness and performance by aligning their digital and sustainability strategies. The dissertation thus enriches IB theory by offering a multi-level perspective on international competitiveness, bridging conceptual fragmentation, extending existing theories, and laying the groundwork for future theorization of the twin transitions in global markets.

3. Practical Implications

The findings of this dissertation suggest several relevant implications for managers and policymakers seeking to navigate the dual transformation toward digitalization and sustainability within the IB context. Collectively, the results demonstrate that these two strategic domains should not be treated as separate or competing imperatives but as interdependent processes whose alignment, when adapted to firm-specific and environmental conditions, can substantially enhance international competitiveness (Guo et al., 2024; Rao & Holt, 2005). Both managerial decision-making and public policy must therefore move beyond linear approaches to embrace flexibility, contextual sensitivity, and long-term capability building.

From a managerial perspective, the research highlights the need for a contingency-based approach to strategy formulation. Managers should recognize that there is no single best way (Lawrence & Lorsch, 1967) toward successful digital-sustainability integration, and the most effective configurations depend on industry structure, technological intensity, regulatory environment, and firm-specific resources. Assessing these conditions allows firms to select an appropriate strategic pathway and to adjust this alignment as external conditions evolve. Managers in SMEs must strike a balance between ambition and pragmatism. Limited financial and technological resources often constrain SMEs' ability to pursue both transformations simultaneously (Denicolai et al., 2021). However, the research underlines the potential of

progressively leveraging complementarities between digital tools and sustainable practices. By systematically investing in workforce training, digital literacy, and sustainability competencies, companies can deliver superior international performance. Moreover, the quantitative findings confirm that technological investments yield higher returns when embedded in sustainability practices. Managers should therefore channel digitalization efforts through sustainability-oriented routines, thereby transforming operational efficiency gains into long-term value creation, enhanced reputation, and competitive differentiation in global markets (Al-Shammari et al., 2022; Ferreira et al., 2023).

Beyond the firm level, the dissertation offers significant implications for policymakers and institutional actors tasked with facilitating the twin transitions. Policy frameworks should move from general support for innovation or environmental compliance to targeted instruments that specifically promote the integration of digital and sustainable transformations. Such instruments may include financial incentives for green and digital investments, grants for technology adoption in SMEs, and streamlined access to international sustainability certifications. Governments should also invest in digital infrastructure, knowledge transfer platforms, and cross-border collaboration programs that allow firms to exploit digital-sustainability synergies more effectively.

Recognizing the heterogeneity of firms is equally crucial. Since strategic alignment is context-dependent, differentiated policy portfolios are necessary to accommodate the diverse approaches firms take to achieve digital sustainability integration. Particular attention should be directed to SMEs and firms in emerging or resource-constrained markets, which often face higher entry barriers to technological and sustainable upgrading (Valero-Gil et al., 2024). Additionally, regulatory coherence across digital and environmental domains is crucial. Fragmented or conflicting regulations can deter firms from pursuing integrated strategies. Policymakers should thus aim to harmonize standards, encourage knowledge diffusion, and

align national and supranational policies with the broader objectives of sustainable internationalization and the twin transitions.

4. Avenues for Future Research

Building upon the findings and theoretical insights from this dissertation, future research should aim to deepen, expand, and refine the understanding of how digital transformation, sustainability, and internationalization interact to shape firm competitiveness and long-term performance. While this research provides a multidimensional foundation, it also highlights important conceptual, empirical, and methodological gaps that necessitate a systematic research agenda. Advancing this line of research requires both replication and extension of the current results in different settings, as well as the development of integrative frameworks capable of explaining the dynamic and contingent nature of the twin transitions in IB. The following avenues outline how future scholarly contributions can enrich this emergent field.

4.1. Broadening Contexts and Enhancing Generalizability

A first and fundamental direction concerns the expansion of the empirical and contextual scope of research. Most existing studies tend to focus on a few institutional settings (e.g., Liu et al., 2024; Zhang et al., 2024; Zhang and Deborah, 2024), where infrastructures, regulatory pressures, and technological readiness are generally similar to one another. However, the dynamics linking digitalization, sustainability, and internationalization are likely to differ significantly across institutional and geographical contexts. Future research should therefore investigate how variations in national innovation systems, institutional quality, and stakeholder expectations influence firms' strategic alignment. Comparative studies between developed and emerging economies could provide crucial insights into the barriers and enabling conditions for pursuing digital-sustainability convergence in diverse institutional environments.

Particularly for SMEs, the internationalization process is deeply intertwined with local resource constraints and institutional pressures (Bag & Pretorius, 2022). Studying SMEs in resource-scarce or institutionally volatile contexts would highlight how institutional voids, infrastructure gaps, and cultural factors shape the integration of digital and sustainable practices. Similarly, sectoral heterogeneity remains largely underexplored (Rao & Holt, 2005). Different industries face distinct technological imperatives and sustainability trade-offs (Broccardo et al., 2023). While manufacturing sectors emphasize efficiency and process innovation, service or knowledge-based industries depend more on digital connectivity, brand reputation, and customer proximity. Future research should therefore incorporate cross-sectoral comparisons to understand how industry-specific contingencies moderate the success of digital-sustainability strategies in driving international growth.

4.2. Unpacking Causal Mechanisms and Strategic Configurations

A second major direction involves unpacking the causal mechanisms and configurations that link digital transformation, sustainability, and international performance. The intersection of these domains remains theoretically fragmented, with a limited understanding of how they interact in practice. Future studies should develop explanatory frameworks that move beyond linear cause-and-effect assumptions toward configurational and dynamic models, capturing complementarities, feedback loops, and trade-offs.

One promising path lies in exploring the dynamic role of internationalization itself, not merely as a background condition (e.g., George and Schillebeeckx, 2022), but as a mechanism that actively shapes and is shaped by digital and sustainable transformations. For instance, different internationalization pathways, such as export-led growth, digital platforms, or collaborative international networks, may differentially influence how firms deploy digital tools to meet sustainability goals. Understanding this two-way relationship would require examining

how international exposure triggers internal organizational change, capability reconfiguration, and governance adaptation. Moreover, the role of international networks and ecosystems as spaces for knowledge, legitimacy, and technological diffusion deserves deeper investigation.

Equally, sustainability should be conceptualized as an active strategic driver in IB (Luo & Zahra, 2023). Future research could explore how sustainability goals reshape digitalization trajectories by altering managerial cognition, stakeholder relations, and organizational identity. Studies might examine, for example, how firms with strong sustainability orientations adopt specific digital solutions to enhance their international reputation and market legitimacy, thereby achieving lasting competitiveness in their international operations.

4.3. Capabilities, Long-Term Consequences, and Performance Outcomes

A third research avenue should focus on the long-term consequences of digital-sustainability integration. Current research often captures short-term performance metrics or static configuration (e.g., Holl and Mariotti, 2022; Khan et al., 2022), but little is known about how firms develop and sustain the capabilities that underpin successful digital transformation over time. Future work should thus examine strategic capabilities, including technological competencies, stakeholder engagement, data management, and ESG alignment, that enable firms to orchestrate the interplay between digital innovation and sustainability objectives. Understanding how these capabilities are built, transferred, and renewed within firms, and how they differ between multinational enterprises (MNEs) and international SMEs, would add critical depth to the literature.

Similarly, research should focus on analyzing the long-term environmental and social consequences of digital transformation in global value chains (GVCs) (Suchek et al., 2023). The presumed synergy between digitalization and sustainability may, under certain conditions, generate unintended side effects such as rebound effects, digital waste, or increased energy

intensity (Valero-Gil et al., 2024; Verbeke & Hutzschenreuter, 2021). Investigating these paradoxes can help scholars and practitioners better understand the trade-offs embedded in digital sustainability strategies. Furthermore, multi-level studies exploring how institutional environments, policy frameworks, and transnational governance mechanisms influence these outcomes would provide a more holistic view of digital- and sustainability-driven internationalization.

Finally, the relationship between Industry 4.0 adoption, sustainability practices, and performance requires further theoretical refinement (Broccardo et al., 2023). Future studies should therefore assess how distinct strategic pathways influence firms' financial, operational, and reputational outcomes. Such analyses could reveal under what conditions integration yields the highest international returns, and when pursuing distinct trajectories may be more effective.

4.4. Embracing Dynamic and Multi-Level Methodologies

Methodological advancements represent a crucial frontier for this research agenda. The interaction between digitalization, sustainability, and internationalization is inherently dynamic, evolutionary, and multi-layered, yet much of the empirical work to date remains static or cross-sectional (Denicolai et al., 2021; Suchek et al., 2023). Future studies should employ longitudinal designs to capture how firms' strategic pathways evolve over time, as well as how they transition and adapt to environmental pressures. Process-oriented and configurational methodologies, such as qualitative comparative analysis (QCA), could shed light on the mechanisms through which firms achieve, or fail to achieve, alignment. Multi-level modeling would also allow scholars to simultaneously examine firm-level strategy, industry-level dynamics, and country-level institutional effects, providing a richer understanding of how context shapes outcomes. Combining these methods with digital tools such as big data analytics, text mining, and machine learning could further enhance the granularity and predictive power

of future research, especially in capturing emerging patterns across large samples or across time.

Moreover, mixed-method approaches should be encouraged to bridge the current divide between qualitative insights and quantitative generalizability. These methods would enable the field to test theoretical propositions derived from qualitative work while maintaining sensitivity to contextual nuances. This methodological diversification is essential for advancing from descriptive and exploratory studies to explanatory and predictive models that can inform managerial and policy decision-making.

4.5. Toward an Integrative and Forward-Looking Research Agenda

Ultimately, the most promising future research lies in building integrative and dynamic models that conceptualize the interaction between digitalization, sustainability, and internationalization as a continuous, co-evolutionary process (Denicolai et al., 2021). Such models should acknowledge the multiple feedback loops that link firms' strategic choices, capability development, and external institutional environments. They should also incorporate the dual role of firms as both agents and subjects of transformation, shaping global sustainability trajectories while being simultaneously constrained by digital and environmental shifts in the IB landscape.

Developing this line of research could position the digital-sustainability nexus as a central paradigm in IB research, complementing and extending traditional frameworks such as the RBV (e.g., Estensoro et al., 2022) and dynamic capabilities (e.g., Díaz-Chao et al., 2021). By conceptualizing these two transitions as both strategic imperatives and adaptive processes, future research could explain how firms not only survive but thrive amid the accelerating technological, environmental, and geopolitical changes of the global economy.

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