When digitalization meets sustainability: exploring interactions within a manufacturing firm

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Abstract

Purpose – This study explores if and how manufacturing firms can achieve an effective interaction between digitalization and sustainability (in economic, social and environmental terms). The main aim of the study is to understand the extent and nature of the interaction between digitalization and sustainability processes and how business firms manage this interaction.

Design/methodology/approach – A qualitative, in-depth, single case study approach is adopted, drawing upon the Actors-Resources-Activities (ARA) framework proposed by IMP studies. The case of Beta – a manufacturer in the mechatronic sector – is longitudinally analyzed via data collected from sustainability reports and interviews.

Findings – Beyond unveiling the main challenges and intervening factors to accomplish digital-sustainable interaction, the study highlights the need for firms to strategically plan and integrate digital and sustainable initiatives to foster such symbiotic interaction, emphasizing the role of activities, actors and resources in achieving a cohesive digital-sustainable journey.

Originality/value – The originality of the research relies upon the longitudinal perspective on the interaction between digitalization and sustainability and the adoption of an IMP-based approach referring to the ARA framework, which finally lead to novel contributions in both academic and managerial terms.

Keywords Digitalization, Sustainability, Interaction, Business networks, ARA framework

Paper type Research paper

1. Introduction

In recent years, the manufacturing sector has been strongly shaped by changes and transformations related to two key challenges: digitalization and sustainability (World Manufacturing Foundation, 2021). On the one hand, digitalization and digital technologies present new opportunities for innovation processes and impact the competitiveness of manufacturing firms (Lorenz *et al.*, 2020). Digitalization enables a higher degree of product and service customization, automation and optimization of operations, improved information sharing, decision-making, resource productivity, flexibility and collaboration (Zangiacomi *et al.*, 2020). On the other hand, manufacturers are increasingly motivated to recognize the link between their operations and sustainability and to prioritize sustainability in their operation strategies (Delbridge *et al.*, 2024; Narayan and Tidström, 2021). While these phenomena have often been studied separately, recent literature increasingly recognizes their mutual influence and interdependence (Chen *et al.*, 2020; Demartini *et al.*, 2019). The interaction between digitalization and sustainability emerges as digital technologies not only increase the competitive advantage of manufacturing firms (Tabacco *et al.*, 2024) and raise industrial standards, but also enable new approaches to sustainability goals through improved efficiency, monitoring and resource optimization, suggesting that these processes do not merely coexist but they rather blend affecting the management and performance of manufacturing firms (Chen *et al.*, 2020; Demartini *et al.*, 2019).

The "innovation challenge" for manufacturers is strongly related to the adoption of digital and sustainable practices. Both digitalization and sustainability imply undertaking

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innovative solutions with a strong impact on the production process, the offering as well as market relationships - upstream and downstream (Boons and Lüdeke-Freund, 2013; Carloni and Galvani, 2024). Despite the potential benefits of digital and sustainable practices, various studies highlight the difficulties and hidden costs behind these choices, in terms of both design and implementation, thus showing the "dark side" of these options (Bohnsack *et al.*, 2022). Such emerging hurdles are borne mainly by manufacturing companies active in traditional sectors, where innovative activities are often impaired by limited advanced technological knowledge and by the legacy of consolidated organizational culture, structures and processes (Struyf *et al.*, 2021; Sklyar *et al.*, 2019). Further complexity could also be concerned with the emerging interactions between digitalization and sustainability and the effort required for managing it (Broccardo *et al.*, 2023a). While some large high-tech multinational companies – such as the Italian company Enel – have set noteworthy examples and developed well-known best practices integrating them (Starace, 2020), existing academic contributions are still fragmented and lack an exhaustive overview of the main patterns and emerging organizational configurations, and provide only limited evidence about manufacturing firms in traditional sectors, where change and innovation processes are more challenging (Acciarini *et al.*, 2022; Demartini *et al.*, 2019; Marzi *et al.*, 2017).

This study argues for the role of relationships and networks in shaping digitalization (Eklinder-Frick *et al.*, 2023) and sustainability (Harrison *et al.*, 2023). Their interaction implies a new layer of complexity that extends beyond the boundaries of individual firms, thus affecting its relationships and business network. Notably, it entails increased complexity in terms of activities to be performed by different actors and their underlying resources. As firms adopt digital technologies and sustainable practices, they engage with an expanded network of actors, such as technology providers, consultants, public organizations and competitors (Melander and Wallström, 2023; Melander and Arvidsson, 2021), as well as uncommon actors to the firm's business portfolio, with the aim to collaborate (Dominidiato *et al.*, 2023) to access, develop and combine complementary tangible and intangible resources (Bygballe *et al.*, 2023). Furthermore, digital and sustainable practices transform existing activities and introduce new ones (Keränen *et al.*, 2023), such as data-driven processes, lifecycle assessments or reporting.

While existing research has begun to explore the relationship between digitalization and sustainability, significant knowledge gaps remain. First, most studies examine these phenomena in isolation rather than their dynamic interaction, particularly in traditional manufacturing sectors (Acciarini *et al.*, 2022). Second, while the network implications of digitalization (Eklinder-Frick *et al.*, 2023) and sustainability (Harrison *et al.*, 2023) have been separately studied, there is limited understanding of how their interaction affects business networks, especially regarding changes in actors, resources and activities (Demartini *et al.*, 2019; Marzi *et al.*, 2017). Third, when explored together, the interconnectedness between digitalization and sustainability mainly concerns the environmental aspects, leaving the social and economic dimensions of sustainability largely unexplored (Chen *et al.*, 2020). This study addresses these gaps by exploring how sustainability comes into play along with the digitalization process of manufacturing companies, and which emerging relational and network effects are provoked by the management of the interaction between digitalization and sustainability. Two Research Questions (RQs) are addressed:

RQ1. How do interactions between digitalization and sustainability processes emerge in manufacturing firms?

RQ2. How do such interactions lead to changes in actors, resources, and activities within business networks?

To explore the interactions between the two processes, this study adopts a business network perspective (Håkansson *et al.*, 2009), drawing upon the Actors-Resources-Activities (ARA) framework (Håkansson and Snehota, 1995) to discuss an exploratory case study of a large company, *Beta*, active in a traditional sector – the machinery industry – and located in the furniture industrial district of Pesaro, in center-Italy. The paper is structured as follows. Section 2 illustrates the existing literature on digitalization and sustainability and outlines recent contributions of IMP scholars. Section 3 describes the research methodology based on a qualitative approach and case-study analysis. Section 4 is concerned with the empirical analysis by identifying three temporal phases. Section 5 critically discusses the main findings of the research. The last section provides concluding remarks, theoretical and managerial implications, limitations and future research suggestions.

2. Theoretical background

2.1 Digitalization and sustainability

Digitalization has transformed entire businesses and industries through digital technologies (DTs) and paradigms that have enhanced a transformative digital disruption (Hervas-Oliver *et al.*, 2021). Industry 4.0 (I4.0) has emerged as a noteworthy solution in the manufacturing industry (Yadav *et al.*, 2020) and has been a key topic on the strategic agenda of many firms in different industries, due to the potential that such technologies hold for optimizing business processes, creating new solutions and developing new business fields (Lichtenthaler, 2021).

At the same time, sustainability has emerged as a business opportunity that companies are integrating within their strategy, operations and organizational culture (Broccardo *et al.*, 2023a). Adapting and organizing for sustainability requires seeking organizational forms and practices in and between organizations, entailing the renewal and redesign of business operations, stakeholder relationships and networks and value-creation processes (Delbridge *et al.*, 2024). This requires in turn organizational innovation and cross-cutting development (Kaipainen and Aarikka-Stenroos, 2022). According to recent studies, both reactive and proactive corporate sustainability strategies might be developed by companies. The former is driven by external pressures (i.e. from policymakers, market demand and orientation and financial resources), while the latter is prompted by resources and motives internal to the organization (Palea *et al.*, 2024).

Only in recent times, digital transformation has extended beyond operational improvements, enabling a transition toward sustainability and has become a strategic imperative, with many companies embarking on a new journey characterized by a digitalization-sustainability interaction. This paradigmatic shift

has been termed "digitainability", that is "the cross-fertilization between the processes of digitalization and sustainable development" (Gupta *et al.*, 2020, p. 3). Indeed, the adoption of DTs and I4.0 platforms has represented a significant development in the transition toward sustainability and in supporting sustainability practices, strategies and agendas (George *et al.*, 2022). In this sense, digitalization has been often described as a useful tool for accelerating the transition toward sustainability (George and Schillebeeckx, 2022) and researchers have identified the existence of opportunities and a potentially virtuous reinforcing cycle deriving from an unrealized potential that would result from combining high levels of digitalization with high levels of sustainability (Broccardo *et al.*, 2023b; Lichtenthaler, 2021). At the same time, unrealized potential emerges from eventually combining high levels of digitalization and of sustainability, shown in three key opportunities: first, the transformation, extension and complementing of established sustainable initiatives by means of digital solutions; second, the realizing of sustainability potentials through the extension of already established digitization initiatives; third, the launch of new strategic initiatives directed at combining and merging digitalization and sustainability from their inception (Lichtenthaler, 2021). These opportunities highlight the varied nature of "digitainability" and its potential to drive both digital innovation and sustainable development by leveraging synergies between them.

Existing studies have focused on the conditions leading to an efficient and positive use of DTs on sustainability. Di Maria *et al.* (2022) showed how the adoption of I4.0 technologies holds positive results under the condition that there is full stakeholder collaboration along the supply chain. Literature has also explored possible drawbacks of the interaction between digitalization and sustainability, giving rise to a debate on the ambiguity of the impacts of DT adoption, raising also social and ethical concerns (Dieste *et al.*, 2023). Other studies have moved beyond the direct effects of DTs on sustainability, arguing for the existence of indirect effects (Bohnsack *et al.*, 2022), which might lead to the realization of unintended sustainable consequences or to the creation of new sustainability-related paths.

Looking at the implementation of DTs and their impact in terms of sustainability, digital tools and technologies can facilitate the implementation of sustainable practices in organizational terms, for example through the optimized management of data and information, the reduction of paper consumption and by supporting the general adaptation of behaviors at the individual, organizational and cultural level (Park *et al.*, 2021). On the other hand, digitalization supports the achievement of sustainable goals at the relational level, both upstream and downstream. Indeed, the chance to build I4.0 and smart factories or the realization of interconnected supply chains simplifies the adoption of more sustainable practices along the entire value chain, from a digitalized manufacturer toward its customers and customers' customers (Belhadi *et al.*, 2022; George and Schillebeeckx, 2022).

There is not only an increasing call for research on the consequences of the pervasive adoption of DTs on sustainability (Bohnsack *et al.*, 2022) at all levels (environmental, economic, social) (Brenner and Hartl, 2021), but there appears to be also a need to investigate what are the unexplored aspects in terms of emerging relational and network effects provoked by the interaction of digitalization- and sustainability-related processes, as well as how the interdependencies between these two challenges are perceived and managed (Lichtenthaler, 2021; Brenner and Hartl, 2021). The exploration of such interactions requires the adoption of a lens enabling the understanding of their complexity and the investigation of emerging interconnections at the inter-organizational and network levels (Harrison *et al.*, 2023). In our study, we focus both on "digital-sustainable" intersections and digitalization-sustainability interactions. The concept of interaction builds upon business network dynamics, where it transcends mere momentary contact between actors to encompass a complex web of connections that generate profound reciprocal influences among actors (Håkansson and Ford, 2016; Ford *et al.*, 2008). Analogously, we conceptualize the same pattern in the relationship between trajectories, distinguishing it from a simple intersection point between them – where reciprocal influences remain limited and episodic – which is arbitrarily defined as intersection. In particular, with intersection we aim to spotlight instances where digital and sustainable elements intersect, without necessarily implying a deeper integration or a mutually reinforcing relationship. Intersections capture points of overlap between two distinct trajectories and refer to specific events, processes or actions that involve both digitalization and sustainability. Interaction signifies a more dynamic relationship, where the two processes are reciprocal driving forces that actively interact and influence each other. Interaction, therefore, describes specific instances where digital and sustainable processes engage with and affect each other, potentially shaping a co-evolution process between the two trajectories.

The next paragraph adds a business network perspective on the phenomenon and introduces the framework for the analysis.

2.2. A Business network perspective to explore digitalization and sustainability

From a theoretical perspective, different mainstream theories and lenses have underpinned sustainability-related empirical research. In a recent literature review, Johnsen *et al.* (2017) pointed at stakeholder theory, institutional theory and resource-based perspectives as the main lenses used to explore the link between business operations and sustainability. Yet, in more recent times, sustainability has been recognized as a network-related issue, as the reorganization of industries - necessary to achieve a sustainable society - "requires systemic solutions by multiple, interconnected organisations" (Harrison *et al.*, 2023, p. 1) and because addressing the sustainability challenge is beyond the individual capabilities of a company (Hellemans *et al.*, 2022; Frostenson and Prenkert, 2015).

In their editorial to a Virtual Special Section on sustainability and business networks, Harrison *et al.* (2023) have identified the current IMP scholarship on sustainability, which has focused – among others – on innovation processes (Keränen *et al.*, 2021), environmental policies and legislations (Baraldi *et al.*, 2011) and actors' mobilization (Finke *et al.*, 2016). Over time, contributions relying on a business network approach have investigated sustainability practices. In particular, Tura *et al.* (2019) have examined the "dark side" of sustainability through the identification of tensions emerging in multi-actor networks when firms implement sustainable business practices. Their

findings reveal that, internally, organizations face budgetary conflicts and employee resistance when implementing technology-intensive sustainable practices. In relationships, tensions emerge from increased complexity and from the need to incorporate diverse stakeholder values. Frostenson and Prenkert (2015) have focused on the internal and external complexities of sustainable supply chain management by providing an alternative view in the form of a sustainable supply network. Internally, firms face difficulties in terms of limited control over sustainability-related resources and challenges in coordinating sustainability efforts across the networked structure of the firm. Externally, strategic interaction with various network actors is needed to obtain relevant resources for sustainability. Firms often lack direct control over resources related to sustainability held by other actors in the network and are confronted with the inability to control the economic, social and environmental expectations of various stakeholders.

Among the earlier empirical studies conducted within the IMP group, green and environmental aspects have been explored (Håkansson and Waluszewski, 2002a, 2002b; Baraldi *et al.*, 2011). Yet, these investigations had technological development as their focus (see also Strömsten and Håkansson, 2007; Håkansson and Waluszewski, 2013, among others), and sustainable considerations – environmental, social and economic – emerged as a side issue, or as a feature of the case study in focus. While sustainability has been addressed within IMP studies dealing with technological development, it can be argued that the interaction between sustainability and technological development remains largely under-investigated, and the two streams appear to be detached with a lack of studies explicitly exploring the link between DTs and sustainability. At the same time, IMP holds the potential as a fitting lens to investigate this interaction and can prove valid in bringing added value to the analysis of DTs and sustainability-related paths (Hamalainen and Salmi, 2023), as any initiative or change toward sustainability will be affected and will affect existing business relationships and require new ones to be established (Vildåsen and Havenvid, 2018). Indeed, the adoption of a business network approach can allow for effectively catching the interrelationships that are activated along a sustainable path and the role of interaction in the implementation of sustainable practices (Vildåsen and Havenvid, 2018; Wagrell *et al.*, 2022).

IMP developed interpretative frameworks for investigating interaction and relationships, among which the ARA framework, which relies on the three interdependent layers of ARA (Håkansson and Snehota, 1995) to describe business interaction. According to the framework, interconnectedness among the three dimensions occurs as activities are performed by actors, who use resources, and what happens in a specific relationship impacts not only the individual organization but also its relationships and the wider network. Thus, relationships can be described as companies connected by activity links, which are sustained by resource ties and interconnected by actor bonds.

Beyond its initial formulation (Håkansson and Snehota, 1995), the framework has been extensively used to analyze network dynamics (Harrison and Prenkert, 2009; Pagani and Pardo, 2017 among others), showing how changes in one layer can trigger transformations across the entire network structure. Within IMP, studies have provided focus on all three dimensions of the ARA model. Studies investigated the actor dimension and particularly how actors' roles evolve over time (Abrahamsen *et al.*, 2012; La Rocca *et al.*, 2017), highlighting how network positions are continuously negotiated and redefined through interactions. Resource configurations in networks have also been extensively investigated from a theory and practice perspective (Prenkert *et al.*, 2022), demonstrating how resources are not static entities but are continuously developed and recombined through network interactions (Baraldi *et al.*, 2012). Finally, the dynamic nature of activities has been explored through the lens of activity patterns (Bankvall, 2014) and interdependencies, showing how activities are continuously adjusted and reconfigured as network relationships evolve.

This framework appears particularly suitable considering the intersection between the multifaceted nature of sustainability – with its social, economic and environmental dimensions – and the transformative impact of DTs. Indeed, ARA allows the exploration of how actors engage in sustainable practices, the rationale behind resource allocation and development for digital initiatives, and how activities fostering sustainability and digitalization are undertaken. Moreover, an inherent feature of the ARA framework is its account for the temporal dimensions, which allows to consider relationships and networks' dynamism in ongoing processes. Through ARA, we are able to track and understand actors' evolution and roles' shifts, resource development and reconfiguration and the dynamic nature of activities intersecting sustainability and digitalization goals. This temporal perspective is key for understanding how the intersection and interaction between digitalization and sustainability unfold over time.

3. Methodology

3.1 Research design

With the aim of investigating how sustainability comes into play along with the digitalization process of manufacturing companies and the related changes in actors, resources and activities within business networks, this study embraced a qualitative methodological approach. Qualitative research reveals helpful to deeply understand empirical phenomena and "gain meaningful insights into circumstances and changes" (Carson *et al.*, 2001, p. 10).

Particularly, an in-depth, single case study methodology was adopted (Halinen and Törnroos, 2005) since it relies on greater flexibility, which allows to capture the complexity inherent in business phenomena (Dubois and Araujo, 2007). Also, it helps reinforce validity and reliability of the research while reducing research biases and related issues (Dubois and Araujo, 2004; Beverland and Lindgreen, 2010). Following Eisenhardt and Graebner (2007), we selected a revelatory case, chosen for its likelihood to offer theoretical insights. Specifically, the case selection followed theoretical sampling criteria (Eisenhardt, 1989), looking for an organization that would:

- provide rich insights into the phenomenon under investigation;
- represent an extreme or unique case in terms of the investigated processes (Yin, 2009); and
- offer opportunities for unusual research access (Eisenhardt and Graebner, 2007).

The empirical setting under investigation is that of *Beta* (the name of the company, as well as the name of projects and other stakeholders, has been anonymized to ensure confidentiality), a leading manufacturing firm located in the mechatronic industrial district in central Italy, producing and distributing woodworking machineries worldwide.

Based on these theoretical sampling criteria, three specific characteristics were identified for case selection:

1 a manufacturing firm with a strong orientation toward innovation;
2 a firm that applied digitalization as one of its main innovative drivers in the last decade; and
3 a firm that is also engaged in sustainable practices and active in implementing sustainable initiatives in recent years.

After a first screening of available companies and an exploratory, informal conversation with *Beta*'s Innovation manager, authors confirmed the suitability of the adoption of *Beta* as the main unit of analysis. The selected company appears particularly relevant for the present research since it has shaped innovation as a distinctive element of its brand over the years. For more than 50 years, *Beta* has been offering its customers cutting-edge machinery, has filed numerous patents, and consistently invested in product and service innovation. This has resulted in a strong push toward digitization and digitalization, through which *Beta* distinguishes itself from competitors and maintains its competitive advantage. Additionally, *Beta*, even though operating in a rather traditional sector, is particularly active in terms of sustainability. As a leading company in Italy and the second in Europe in its sector, *Beta* is also at the forefront from a sustainability perspective in mechatronics. Recently, *Beta* has been implementing numerous sustainable initiatives, actively integrating new technologies into the green transition. *Beta*'s technological and sustainable progress makes it a unique company in its sector and worthy of further exploration.

The research design followed a step approach. First, the authors collected data from multiple sources, they secondly triangulated the data and prepared the coding. Third, data were coded by means of an Excel spreadsheet and analyzed by adopting the ARA model (Håkansson and Snehota, 1995). The ARA framework, beyond being particularly helpful in observing and conceptualizing digitally related phenomena (Carloni and Galvani, 2024; Mosch *et al.*, 2022; Andersson and Mattsson, 2015), also supports the investigation of sustainability and the understanding of the underlying mechanisms at the network level (Johnsen *et al.*, 2017; Insanic and Gadde, 2014; Gadde and Håkansson, 2001). Therefore, the ARA model has been adopted within this research as the main analytical lens to interpret data, with the main objective to detect intra- and inter-organizational implications of digitalization and sustainability, as well as their interconnections.

3.2 Data collection

The process of collecting data relied on a combination of primary and secondary sources. The main source of primary data consisted of the company's sustainability reports from 2017 to 2022. This choice is consistent with other recent studies investigating sustainability and relying on the analysis of sustainability reports (Torelli *et al.*, 2020; Higgins and Coffey, 2016). The six reports were analyzed in great detail in their structure and content to get a comprehensive understanding of the company's commitment toward sustainability and the practices and initiatives it implemented in both digital and sustainable terms. The consulted reports were retrieved online on *Beta*'s website; they were written in Italian, and the average number of pages was 139,8.

As *Beta* has been a publicly traded company for several years, its sustainability reports are very detailed and rich in content. Each report includes information about completed, ongoing or newly initiated digital and sustainable projects, along with details about the expected and achieved outcomes of each project, the impacts on the three pillars of sustainability (economic, environmental and social), the actors involved throughout the supply chain, the related activities and the collateral benefits. All the reports provided the same content structure: they included an introductory section with general information on *Beta* and three following sections with detailed information on sustainability: the economic sustainability section – which also includes information on the digitalization projects embraced by *Beta*, the social sustainability section, and the environmental sustainability section.

The secondary data source was a set of semi-structured interviews (Kvale and Brinkmann, 2009). Interviews were conducted in the timeframe from July 2020 to June 2023. Authors integrated interviews with critical actors each time the available information was insufficient to understand the phenomena under investigation and their underlying implications deeply. In this sense, interviews aimed to fill information gaps and disclose "important and often hidden facets of human and organizational behavior" (Qu and Dumay, 2011, p. 246). The interviewees are professionals who play (or played) a crucial role in *Beta*'s digitalization, sustainability process or both. Every interview lasted 45–70 min and was conducted in Italian, recorded and transcribed *verbatim*.

Authors conducted interviews with six professional figures within *Beta* and its business network: the Innovation manager of *Beta* (operating in the Strategy and Sustainable Development division), the CEO and Founder of a key partner (*GreenA*) – a consulting firm developing sustainable projects in cooperation with *Beta*, the Senior Project manager of a technological services business provider (*TechInt*) who developed a digitalization project in partnership with *Beta*, the CEO Assistant for Innovation, the Corporate Social Responsibility (CSR) manager and the Key Account and Dealers manager (operating in the Sales division) of *Beta*. Table 1 details the interviews.

Considering that interviews were used as a secondary source of information and primarily to supplement details on facts or events already known to the authors, a formal interview protocol was not developed. Instead, a set of themes were explored with each interviewee, allowing space for personal reflections and insights that could enrich the overall perspective, in line with Jiménez and Orozco (2021) calling for a set of topics to be explored more than specific questions to guide interviews. Initially, interviewees were asked broader and more general questions about the topic under investigation with a focus on sustainability or digitalization depending on the professional role involved (e.g. Which digital/sustainable initiatives did *Beta* pursue in the last 10 years? Which actors were involved? What are you expecting for *Beta*'s future in both digital and sustainable terms?). Subsequently, the interviews

Table 1 Interviews' details

Interviewee	Firm	Topics	Date and duration
Innovation manager	Beta	Ongoing digital initiatives in beta and sustainable impacts, collaborations with key actors, future steps	19/06/2023, 45 min
CEO and founder	GreenA	Nature and features of Beta-GreenA collaboration, sustainable efforts, business network dynamics	19/06/2023, 70 min
Senior project manager	TechInt	Nature and features of Beta-TechInt collaboration, challenges of digital initiatives, link among ongoing initiatives	03/07/2020, 63 min
CEO assistant for innovation	Beta	Beta digitalization process over years and expectations for the future	13/09/2021, 52 min
Corporate social responsibility manager	Beta	State of the art of beta sustainable initiatives, link between digital and sustainable initiatives, business network dynamics	13/02/2023, 46 min
Key account and dealers manager	Beta	Implications of digital and sustainable initiatives along the supply chain	23/11/2022, 55 min

Source: Author's own work

delved into specific projects in which the interviewees had actively participated. The second part of the interviews thus focused on individual projects to better understand their implications in terms of actors, activities, and resources from an inter-organizational perspective (e.g. How were you involved in the project? Which kind of activities were you asked to deploy? How did *Beta* acquire the resources needed for the project?).

Exploring the viewpoint of the CEO and Founder of *GreenA* and the CSR manager of *Beta* was paramount to gaining insights into *Beta*'s sustainable path over time, its main intra-organizational implications and its potential interrelations with other business areas. At the same time, the perspectives of *Beta*'s Innovation manager and *TechInt*'s Senior Project manager were helpful in untangling *Beta*'s digital evolution and the strategic choices undertaken along the journey. Finally, the voices of the CEO Assistant for Innovation and the Key Account and Dealers manager of *Beta* were of high importance to understand how both the digital and sustainable paths of *Beta* unfolded, if and when they overlapped, and which consequences this entailed, beyond better depicting the role and influence of external actors along them.

Other secondary sources that the authors consulted to achieve further details on the case study are the company's website, sectorial magazines, editorials, press briefings and corporate reports. Exploration of such data allowed the authors to fully understand the company's context, generating new knowledge while minimizing the burden on interviewees (Ruggiano and Perry, 2019), and added nuance to the collected information.

3.3 Data coding and analysis

Our data coding and analysis is grounded on the systematic combining (Dubois and Gadde, 2002, 2014) as the primary analytical framework, which enables a continuous interplay between theory and empirical data. This approach allows to account for the significance of theoretical pre-understanding while maintaining openness to empirical findings, thus enabling a dynamic interplay between theory and data throughout the research process.

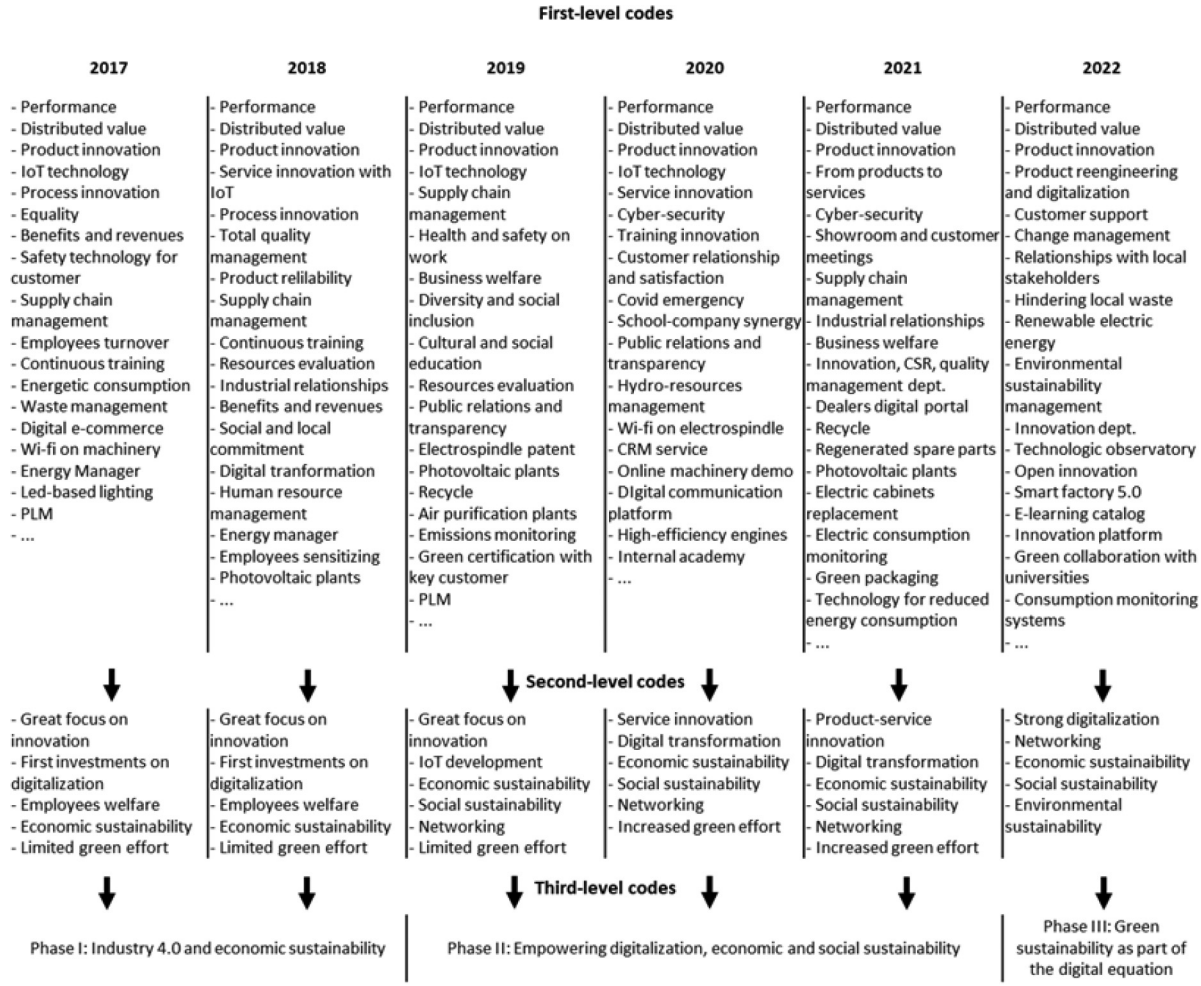
The data collected from the sustainability reports, interviews and additional secondary sources were coded by means of a shared Excel spreadsheet. The coding process was manual and relied on the iterative identification of main topics emerging from data; therefore, the coding process can be described via steps. In the first step, a dedicated file was created containing all the information gathered along data collection, categorized by data source, data type, timeframe and content. Successively, relevant keywords and key concepts were highlighted in the file and constituted the first-level codes. Such codes were analyzed by both authors to identify recurring elements until they were condensed into a set of main topics for each year of analysis (second-level codes). As mentioned above, data coding and analysis followed a systematic combining approach (Dubois and Gadde, 2002), using what Dubois and Gadde (2014) term a "tight and emerging" logic. This logic involves the continuous elaboration of research findings, which take on different forms as data are collected, and the authors refine them over time based on foundational theoretical elements. In the specific case, the first-level codes were double-checked with available theory on the topic to make sure no relevant concepts were overlooked. In some cases, this led authors to expand the data collection to fully cover the range of topics addressed by literature. Similarly, second-level codes assumed different shapes along the research development, as a result of combining theoretical and empirical conceptualization efforts. Finally, the second-level codes converged into the identification of three main phases in *Beta*'s digital and sustainable journeys (third-level codes). Again, as a result of systematic combining, authors experienced an ongoing reworking of the shared results table, which underwent numerous revisions before being used in its final form to conceptualize the empirical framework proposed in the Discussions section. An iterative process of validating results through continuous verification of emerging hypotheses against the available literature was implemented. This process, akin to a continuous revision of the initial hypotheses, allowed to generate new research outcomes being primarily driven by the empirical context (Dubois and Gadde, 2014).

The phases mirror the development of an interaction between digitalization and sustainability (economic, social and environmental) efforts, that is:

- *Phase I* (2016–2018) - Industry 4.0 and economic sustainability.
- *Phase II* (2019–2021) - Empowering digitalization, economic and social sustainability.
- *Phase III* (2022-ongoing) - Green sustainability as part of the digital equation.

Figure 1 provides a graphic summary of the coding process. For each of the identified phases, authors highlighted the main

Figure 1 Extract from the data coding process



Source: Authors' own work

digitalization and sustainability-related processes (including projects, intra-organizational changes, initiatives and activities), starting from a "pilot" digital project launched in 2015/2016 (PLM). Notably, they also recognized the possible impacts of *Beta*'s digital transformation on sustainability-related aspects.

Data was interpreted through the three interrelated dimensions of the ARA framework introduced in Section 2. Indeed, for each of the main digitalization and sustainability-related initiatives identified, the authors analyzed how the company engaged in relationships with actors, the main resources (both organizational and physical resources), and activities. A detailed description of each phase through the ARA lens is provided in the following section.

4. Results

4.1 Phase 1 (2016–2018) - Industry 4.0 and economic sustainability

4.1.1 The start of Beta's digitalization journey

Beta has a strong innovative identity, and its technological path starts many years ago, but the past two decades turn out to be crucial in consolidating the innovative focus of the firm. In 2007, the company embarks on its digital transformation journey, with the aim of converting internal processes to a digital format and supporting a digitally based innovation journey. The initial years combine small, short-term oriented initiatives, while a key activity arrives in 2015 with the adoption of a product lifecycle management (PLM) technology to monitor information at every stage of the product life cycle along the entire supply chain and with an integrated approach. The PLM is customized for *Beta* with the support of an external technology supplier. The project requires the adoption of consistent resources, that is monetary ones and the organizational effort to train and adapt the working procedures of employees.

In 2016, fiscal incentives are allocated from the Italian Ministry of Economic Development for companies investing in I4.0 technologies. This represents one of the main drivers of innovation for many customers of *Beta*, especially small and medium companies in the furniture sector. *Beta* is therefore pushed to adopt I4.0 technologies in the attempt to be innovative. A digitally based Activity is launched with the support of a technology provider – the "Spare parts"

application, which consists of a digital platform to sell and distribute spare parts to customers. A concurrent initiative is "Zero Defect", a project in collaboration with two Universities and two regional entities dedicated to applying Industrial-Internet-of-Things (IIoT) technology to the electro-spindles installed on *Beta* machineries. Both initiatives, beyond requiring time and dedicated human resources, represent a relevant financial effort for *Beta*.

However, the most impactful project is the launch, in 2016, of the IIoT-based application that guarantees customers remote control of machineries and quick interventions, together with the possibility to access *ad hoc* digital service packages. The IIoT-based application is a game-changer in the innovative path of *Beta*, paving the way for a new business model oriented toward Digital Servitization. The project, implemented in co-partnership with a trusted Actor- *TechInt*, led to an internal reorganization of the firm, with the emergence of a Service Innovation Unit and the integration of a Service Innovation Director. Collateral activities are launched in relation to the IIoT-based application, such as informative/training sessions with customers and employees, internal contests for service innovation, dedicated marketing and communication campaigns or alignment sessions with subsidiaries and dealers.

4.1.2 The focus on economic and social sustainability

The digital push of *Beta* contributes to the achievement of some goals in terms of economic sustainability. No specific project or activity defines the start of *Beta*'s sustainable journey, which can conventionally coincide with the first sustainability report in 2017, prompted by the compliance with the European "non-financial directive". Projects such as the PLM, IIoT-based application or Zero Defect support the economic stability of *Beta*, leading to greater economic performance, an increase in the economic value distributed among stakeholders, additional innovation in both products/services offering and their usability.

The sustainability journey of *Beta* is not limited to the achievement of goals in the economic sustainability pillar. Social sustainability, indeed, is reflected in initiatives aimed at improving the conditions of the surrounding society, even though they do not necessarily include a digital dimension. For instance, *Beta* is committed to reducing internal turnover, improving safety and healthy working conditions, enriching the company welfare, enlarging the set of fringe benefits or supporting the local territory with initiatives about social inclusion, culture and equal opportunities. In 2018, *Beta* takes its first digital step toward social sustainability by adopting a new ERP module dedicated to Human Resource (HR) Management.

In 2017 and 2018, *Beta* began incorporating environmentally sustainable business practices, such as the appointment of an Energy manager, the adoption of LED-based lighting or the introduction of solar panels to increase energy self-sufficiency. To reduce waste and decrease the overall electric energy consumption *Beta* implements new technologies that allow for the optimization of energy levels and their constant monitoring.

4.2 Phase 2 (2019–2021) – empowering digitalization, economic and social sustainability

4.2.1 The consolidation of Beta's digitalization journey

From 2019 to 2021, *Beta* continues consolidating its digital transformation by introducing new initiatives while preserving earlier ones. A notable new initiative is the realization of a software package that optimizes the user experience of machinery; it calls for the adoption of human and economic resources. *Beta* also extends the application and rollout of a new CRM system worldwide, involving selected partners to access resources such as global competence and experience in digital solutions. It requires a consistent effort in terms of adjusting employees' working routines and transferring technological know-how from the headquarters to all the subsidiaries. To achieve greater integration and reduce external information asymmetries, *Beta* develops a "light" version of the CRM for dealers, in collaboration with the CRM provider.

In 2021, the firm launches an "Innovation in Action" unit as part of a larger Open Innovation project. It is an organizational unit involved in a formal pipeline with an Israeli technological observatory and a local consultancy agency, *GreenA*. The latter has a crucial role in this project since it represents the official contact through which *Beta* is able to externalize sustainability-related know-how. The agency holds knowledge and experience on approaches of circular economy and sustainability from a business perspective.

4.2.2 Social and environmental sustainability efforts

From a sustainability perspective, the second phase of *Beta*'s journey witnesses a reinforced link between the digitalization journey and the achievement of economic sustainability goals. Indeed, the digital updates further contribute to improved economic performance, increased economic value distribution, enhanced customer satisfaction and improved management of the supply chain relationships.

The company's focus on social sustainability grows through new digital activities like the "Digital Stage" online platform, created with the support of a local technology provider and aimed to host digital events such as live training sessions, live demonstrations on machineries and online fairs. Other formats, such as "Talking Technologies" and "Digital Talk & Training", are initiated to help customers overcome physical limitations imposed by the COVID-19 pandemic and exchange ideas with customers and other stakeholders. To implement these activities, *Beta* invests considerable financial resources, along with human capital, know-how and time.

Regarding green sustainability, the second phase of *Beta*'s journey encompasses the conservation of the activities started during the first phase, without the introduction of new initiatives or projects. What changes is the introduction, in 2021, of a CSR manager, which slightly modifies the organizational asset of *Beta*, calling for new resources and activities, such as readdressed people involved in sustainable practices or the activation of internal procedures, analyses and business cases on the topic. Also, one key customer of *Beta* pushes the firm to achieve higher standards in all three pillars of sustainability. Indeed, it asks *Beta* to take part in a property ethical code including several rules that the entire supply chain should address in terms of green, social and economic sustainability (which *Beta* is evaluating in this phase).

4.3 Phase 3 (2022-ongoing) – green sustainability as part of the digital equation

4.3.1. Advancing digital initiatives

In 2022, Beta further consolidates the digital projects and initiatives started in the previous phases, expanding them with

additional activities. For instance, the e-learning courses and training sessions provided in the "Digital Stage" are widened with new topics and further visual material. A new project starts at the end of 2022, offering periodic training sessions to strengthen the technical competences of both customers and internal workforce, reinforcing the link between digitalization and social sustainability. The digital activities introduced or maintained support *Beta*'s goal to offer continuous educational opportunities, to improve the working conditions of employees and establish a healthy working environment, and to facilitate the relationship with local communities and stakeholders.

4.3.2 The integration of environmental sustainability and future directions

Simultaneously, *Beta* implements initiatives to bolster economic sustainability, such as the adoption of a formalized monitoring procedure to assess the firm's innovation performance and product development reengineering. New digital activities enumerate a project called "I5.0" aimed at investigating advanced IIoT solutions for the realization of smart factories in collaboration with a local University and regional entity. The company's Digital Servitization journey continues with an expanded service offering for both customers and dealers. All these actions reinforce the economic performance of the firm and contribute to the spread of increased economic value.

Finally, in relation to green sustainability, 2022 and 2023 witness greater efforts from *Beta*. Training sessions for employees (involving top and middle management) are initiated to promote awareness of green practices. Additional initiatives focus on waste reduction, new plants for energetic efficiency or the improved management of hydro resources. Such activities constitute a great investment in terms of economic resources and a relevant effort in terms of coordination, management and operability. Recently, the key customer that proposed *Beta* to adhere to its ethical code during phase two has pushed the proposal again. *Beta* is called to take a decision over the next months, so as not to jeopardize the long-standing relationship with the key customer.

During this period, the Innovation in Action unit establishes inter-organizational relationships with Italian and international universities to implement sustainability-oriented projects. These include a wood-furniture supply chain sustainability project in collaboration with an Italian university and a Horizon 2020 project on circular economy - in collaboration with a Swedish university - for recycling waste wood into fiberboard and new construction products. The company also starts delivering innovation- and sustainability-themed workshops with a research center and certifying body located in Northern Italy.

Looking ahead, *Beta* is preparing to launch new green sustainability projects, including a deep analysis of CO2 emissions in the selling of machinery components (both new purchase and regeneration) to identify best practices that reduce air pollution, or the detailed evaluation of CO2 impact of digital services. *Beta* currently lacks a digital tool that allows the integration, analysis and evaluation of the real and potential green performance levels. Implementing new tools in this direction would represent a first bridge between digitalization and green sustainability.

Table 2 presents a summary of the three phases identified both for digitalization and sustainability processes depicted through the ARA framework.

5. Discussions

The analysis of the *Beta* case provides interesting insights, which could be discussed in terms of the type and features of the journey – answering our first RQ "How do interactions between digitalization and sustainability processes emerge in manufacturing firms?" – and their evolution along the ARA dimensions - thus addressing the second RQ identified "How do such interactions lead to changes in actors, resources, and activities within business networks?". It is apparent that in the last eight years the company has been engaged with both digitalization processes and sustainability initiatives, which have started as autonomous activities based on different strategic objectives and organizational contexts and then, in recent times, have crossed one with the other along specific projects and settings, as will be explained below (Figure 2).

5.1 The emergence of interactions between digitalization and sustainability processes

5.1.1 An overview of the two journeys and of their interactions

The "digitalization journey" has been launched through specific projects and then has become a key concern for top management pursuing the combination of digital innovation with a stronger orientation toward Digital Servitization (Gebauer *et al.*, 2021). The digitalization process shows, on the one hand, the implementation of structured and formal activities, having specific strategic objectives. On the other hand, this process shows an "inside out" logic where there has been an effort to align internal resources and organizational processes with those provided by technology and business partners. Since the beginning, the company has displayed a strong awareness about the implications of introducing advanced digitalization processes and has been keen – also thanks to technology partners – to promote stronger integration of IT systems and tools.

The "sustainability journey", instead, has been characterized by an "outside-in" logic as external pressure for a more sustainability-oriented profile (Bansal and Roth, 2000) has increased over time pushing the company to undertake systematic reporting first (Harrison *et al.*, 2023; Bayne *et al.*, 2021), and then to further implement specific projects and activities more related to economic and social sustainability dimensions. This has meant gaining an incremental awareness of nature and features of all sustainability principles and approaches, initially managed in a fragmented manner, implementing scattered initiatives without a clear sustainability-related strategic objective. This has resulted, on the one hand, in *ad hoc* training of employees on sustainability issues and, on the other hand, in designing and starting projects and activities with key partner firms and organizations (Bayne *et al.*, 2021), in product and process-related sustainability-oriented innovations more linked to the green dimension.

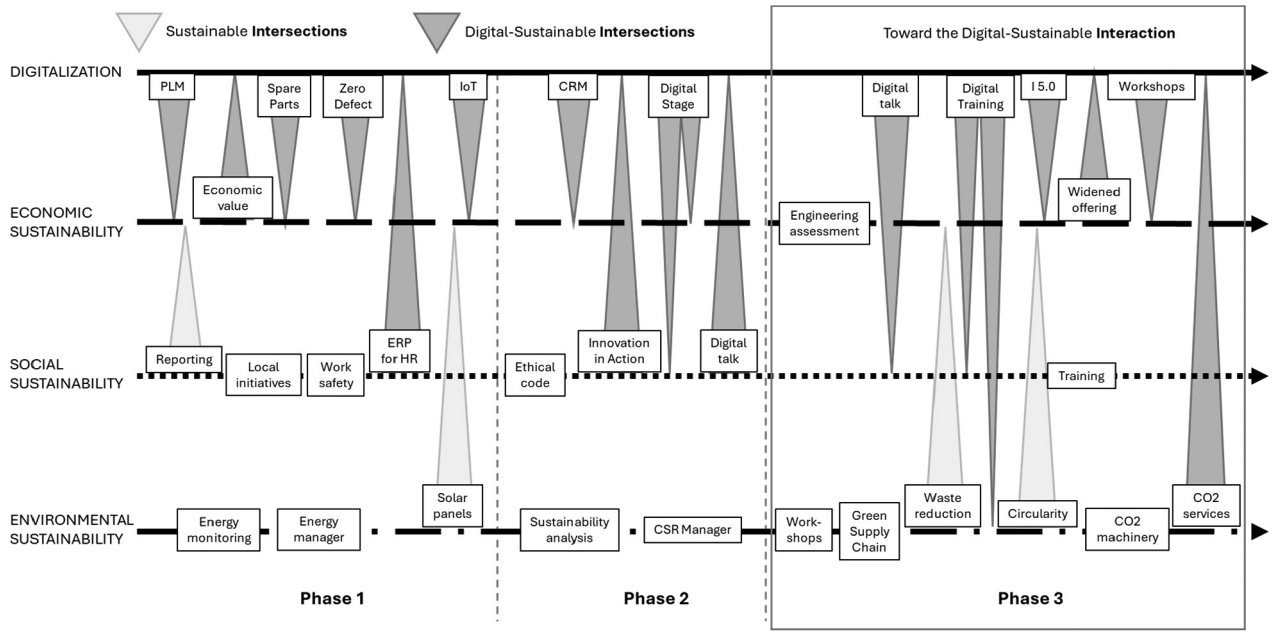
Beta's case empirically validates Lichtenthaler's (2021) key opportunities for digital-sustainable integration, particularly the realizing of sustainability potential through existing digitization initiatives, such as PLM and Zero Defect projects,

Table 2 Digitalization and sustainability: phases, actors, resources, and activities

	Digitalization			Sustainability		
	Phase I	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
Actors	- Technology providers and IT suppliers - Beta customers - Local universities - Regional entities - Service innovation unit - Service innovation director	- Technology providers - Local consulting firm - Israeli observatory - Innovation in action unit	- Local universities - Regional entity - Beta customer	- Energy manager - HR department - Marketing department	- Innovation in action unit - Innovation consulting firm - CSR manager - Key customer	- CSR manager - HR department - Training suppliers - Universities - Horizon 2020 partners - Innovation in action unit - Key customer
Resources	- Digital resources (PLM technology, spare parts platform, IoT solution, ERP system) - Financial resources	- Digital resources (software for machinery, CRM software, digital stage platform, software package) - Financial resources - Human resources - Organizational resources (new innovation unit)	- Financial / economic investment - New digital tool	- ERP system with HR application - Solar panels - Economic / financial resources	- Digital stage platform - Economic / financial resources - Human resources - Know-how and codified knowledge	- Digital stage platform - Economic / financial resources - Human resources
Activities	- Projects-related activities (PLM project; spare parts project; zero defect project; IoT project, ERP development project) - IT training	- Projects-related activities (IoT project, CRM project and extension to dealers, digital stage project) - Digital talk live & training - Adjustment of working routines - Training sessions for technological know-how transfer	- Digital training - I5.0 project - Workshops - Digital services impact analysis	- Sustainability reporting - Increase in economic value for stakeholders - Efforts to ensure work safety, reduced turnover, company welfare, fringe benefits - HR management and welfare - Energy consumption monitoring - Solar panels for energetic self-sufficiency	- Ethical code development - Observations from innovation in action - Digital talk live & training - Talking technologies - Sustainability analysis and business case	- Training (IT, techinical, on sustainability) - Economic assessment of engineering activities - Widened product / service offering - Waste reduction - Circularity projects - Analysis of CO2 emissions of machinery - Assessment of CO2 impact of digital services - Workshops on sustainability

Source: Author's own work

Figure 2 Beta's digitalization and sustainability journeys: intersections and interactions along phases



Source: Authors' own work

and the establishment of new integrated digital-sustainable initiatives materializing through initiatives like Digital Training.

The company's journey also provides new insights into the debate on reactive versus proactive sustainability strategies (Palea *et al.*, 2024). Beta's sustainability journey began reactively, driven by external pressures (Bansal and Roth, 2000) but evolved toward a more proactive approach, particularly when integrated with digitalization initiatives (Kaipainen and Aarikka-Stenroos, 2022).

The empirical analysis shows that throughout these journeys, which have implied complex transitions, several intersections have emerged, linking the digitalization effort to specific sustainability dimensions. The last phase unravels a deeper connection between digitalization and sustainability, resulting in increased synergies. Figure 2 visually represents the digitalization-sustainability intersections and interactions along *Beta*'s journey. The four arrows in the figure depict *Beta*'s journey over time, encompassing both the digitalization and sustainability aspects, with the latter split into pillars (economic, social and environmental). White boxes indicate the main projects and activities developed by *Beta*, while triangles denote whether such projects/activities allow for an intersection between their originating journey and the others. Specifically, light-gray triangles indicate intersections within the three pillars of sustainability, and dark-gray ones signify intersections between the digitalization and sustainability journeys.

As visible from the picture, activities play a crucial role in facilitating the level of integration between the two journeys. Indeed, it is mainly through the launch of new activities along the three phases that digital-sustainable intersections start to be addressed and consolidated over time. However, the implemented activities are highly specific and focused on isolated business goals - especially during the first phases, leading to a lack of integration among the three sustainability pillars (economic, social, environmental) and digitalization.

5.1.2 The unfolding of interactions throughout the three phases

The first phase demonstrates what Bohnsack *et al.* (2022) describe as indirect effects of digital transformation on sustainability, particularly in the economic dimension. The significance of activities becomes particularly evident in the first phase. Notably, most intersections occur between digitalization and economic sustainability. On the one hand, various digital projects, such as the PLM, Zero Defect or the IIoT one, contribute to *Beta*'s economic sustainability journey. It is noteworthy that these activities were not originally conceptualized as digital projects with sustainable impacts but were later reconsidered during the preparation of the sustainability report. On the other hand, certain sustainable initiatives reinforce the digitalization journey of the firm (Lichtenthaler, 2021). For example, *Beta*'s generated economic value enabled investment in new projects, and an increase in HR activities for social purposes led to the implementation of a dedicated ERP. In essence, the first phase of *Beta*'s journey underscores a strong intersection between digitalization and economic sustainability, along with the initial signs of an intersection between digitalization and social sustainability. Although green sustainability emerges as a priority for *Beta* during this phase, initial activities in this regard do not yet reveal an intersection with digitalization.

The second phase of *Beta*'s journey demonstrates increased engagement from internal and external actors in managing ongoing activities and initiating new ones, necessitating additional resources. During this phase, top management becomes aware of the need to enhance integration and coordination of all innovation-oriented initiatives, including those related to digitalization and sustainability. This recognition

prompts the establishment of key units and positions, such as the Innovation in Action unit in collaboration with *GreenA* and the appointment of a CSR manager. *Beta*, by initiating a partnership with *GreenA* – specialized in the wood-working sector with strong expertise in circular economy, reinforces its visibility both internally and externally, thus leading to a necessary renewal and redesign of business "organizing", stakeholder relationships, and value-creation processes (Delbridge *et al.*, 2024). This evolution results in the creation of an "inner" network of actors dealing with digitalization and sustainability issues. Consequently, *Beta* starts addressing and planning sustainability-related projects concerning the production and product settings. In particular, digitalization projects like the CRM and Digital Stage contribute to economic sustainability, while socially sustainable initiatives like Innovation in Action and Digital Talk reinforce the digital efforts of the company. Additional efforts are made to further implement sustainability by developing new activities with both social and environmental implications. Despite these achievements, such efforts remain somewhat isolated from the other journeys. Therefore, following the wave embraced during the first phase, the second one remarks on the established intersection between digitalization and both social and economic sustainability. However, such intersection is predominantly formalized "ex-post" in sustainability reports rather than led by integrated business decisions. This phase still lacks activities meant to create a bridge from digitalization to environmental sustainability. Not only that, missing opportunities for integration also emerge among the three sustainability pillars, which provide no interconnections.

In the third phase, available digital resources, such as the Digital Stage platform, are used for further developing training activities on social sustainability issues (see, for instance, the Digital Training and Digital Talk activities), with digitalization accelerating the transition toward sustainability (George and Schillebeeckx, 2022). Organizational reconfiguration opens the way for further consolidating digitalization and economic sustainability-based processes and activities. For instance, the development of a new, service-based offering initially aimed at economic sustainability ends up contributing to the enhancement of digital tools for this purpose. Also, the implementation of the I5.0 initiative for digitalization plays a role in improving *Beta*'s economic sustainability outcomes. During this phase, *Beta* makes significant strides in environmental sustainability on two fronts. First, several green initiatives start, consolidating the environmental commitment of *Beta* while fostering greater integration among the three sustainability pillars. Second, the assessment of the CO2 impact of digital services and the design of new tools to limit greenhouse gas emissions mark the first sign of the intersection between environmental sustainability and digitalization. Throughout this phase, *Beta*, influenced by external actors such as key customers or dealers, gains full awareness of the necessity for a more integrated approach among the three sustainability pillars, recognizing digitalization as a key leverage. Consequently, in this last phase, the observed company invests in new activities and resources with local and distant actors aimed at achieving a comprehensive interaction between digitalization and sustainability across its social, economic and environmental dimensions. The third phase is pivotal in *Beta*'s evolutionary path, marking the transition from emerging intersections between digitalization and sustainability to a more cohesive interaction, with active and – in most cases, consolidated – interconnections among all journeys. However, there is still room for improvement in emphasizing and exploiting the interaction among the three sustainability pillars.

The case of *Beta* sheds light on the idea that companies adopting digitalization and sustainability as simultaneous, yet parallel, pathways can foster an interaction between the two; however, this is a process that demands time and significant effort from the company. A critical factor that could compromise the digital-sustainable interaction is the absence of planning for sustainable initiatives with a synergistic set of operations enabling alignment among the three pillars (economic, social and sustainable). When sustainable initiatives emerge sporadically without a cohesive plan for joint activities, achieving an interaction among sustainable pillars becomes increasingly complex. The underlying issue is related to the decision-making process of managers in defining the sustainable strategy of the firm. For companies like *Beta*, the idea to integrate sustainable initiatives from different pillars may emerge as "ex-post" and not "ex-ante". To attain an optimal condition, where the symbiotic interaction among sustainability pillars precedes the integration between the digital and sustainable journeys, such firms will require additional time to undergo a cultural transition and recognize the benefits of joint strategic planning.

5.2 The impact of digitalization and sustainability on business network dynamics

From the ARA perspective (Håkansson and Snehota, 1995), the empirical analysis highlights how a genuine interaction between digitalization and sustainability becomes feasible when actors, activities and resources are meticulously considered and intertwined. In particular, activities play a pivotal role in initiating intersections between these two journeys, serving as effective levers that trigger multiple purposes. Numerous examples in the case of *Beta* underscore that a new digital activity can contribute to sustainable goals, and conversely, a sustainable initiative can drive the firm to invest in new digital tools.

Two types of activities can be recognized as particularly relevant since they can accelerate the achievement of digital-sustainable interaction. The first type, which can be renamed as "bidirectional" activities, refers to those that initially emerge within one of the two journeys but have implications on the other. Over time, such activities manifest a reciprocal outcome and contribute once again to the initial journey. In *Beta*, this was exemplified by the Digital Talk initiative, which originated as a digital project with social implications. Later on, the firm recognized the social effects it generated and, in an effort to enhance it, improved the technological performance of the Digital Stage platform, showcasing a shift in the direction of the contribution. The second type, renamed "multi-intersection" activities, refers to those born with the intention of contributing to more than one journey. With a multi-level purpose, these activities enable companies to achieve results in the digital-sustainable journey by reducing and optimizing resource consumption. In *Beta*, an example of a multi-intersection activity is Digital Training, which emerges as a digital activity with implications for both social and economic sustainability.

Nevertheless, activities alone create intersections but are insufficient to achieve a proper digital-sustainable interaction.

To accomplish this, a key element is the firm's ability to create and operate within a stable business network, comprising enduring relationships with key actors (Vildåsen and Havenvid, 2018). The importance of stable business networks in achieving digital-sustainable interaction also aligns with insights from Hellemans *et al.* (2022), who highlight the role of diverse stakeholders and the importance to integrate activities of a wide variety of actors to address sustainability challenges. The interconnections resulting from these business relationships enable the focal firm to consolidate ongoing activities with the support of highly competent partners, with whom new projects can be designed toward digital-sustainable interaction. Finally, resources serve as the "engine" propelling the innovative path of a firm, thereby enabling both the digitalization and sustainability journeys, as well as their interaction.

6. Conclusions

This research aims to understand to what extent and how digitalization and sustainability processes interact with each other in manufacturing firms. To reach this aim, the study presents and discusses the empirical case of an Italian manufacturing firm active in a traditional sector. The analysis highlights three main insights.

First, the digitalization and sustainability processes start with different timings, objectives, modes and premises. In the first and second phases, they intersect (i.e. instances where elements of the two processes touch upon each other), while in the last phase, a synergistic interaction between the two processes unfolds, characterized by more dynamic relationships and reciprocal influence.

Second, the case of *Beta* highlights how bridge the gap between digital and sustainable initiatives can be far from easy. In some cases, firms could find it simpler to approach two distinct journeys, the digital and the sustainable ones, and exploit growing experience and awareness in both fields to finally achieve an effective integration. Indeed, although this approach requires the consistent adoption of key resources involved in a multitude of new activities, both at the digital and sustainable level, it allows for the smooth transition toward both initiatives and for the cultural adaptation of all actors involved in the process, both at the intra- and inter-organizational levels.

Third, the empirical observation of the case also stresses the significance of activities and supports the idea that activities should be reconfigured to facilitate network mobilization and leverage digital-sustainable interconnections (Harrison *et al.*, 2022).

From a theoretical standpoint, this research provides two main contributions to literature. First, the study answers the call for research on the interaction between digitalization and sustainability processes (Bohnsack *et al.*, 2022; Brenner and Hartl, 2021), and reveals the dynamic and evolutionary nature of their interaction. Previous research has traditionally examined these phenomena in isolation (Acciarini *et al.*, 2022), by adopting a longitudinal approach to the digitalization and sustainability journeys undertaken by a manufacturing firm and emphasizing its temporal evolution. Instead, we provide new understanding of actors' evolution and roles' shifts, resource development and the dynamic nature of activities intersecting sustainability and digitalization goals. By identifying distinct phases in this evolution – from parallel journeys to unintended sporadic intersection and finally to intended interaction – we provide a temporal overview on how the interactions between digitalization and sustainability emerge and mature. This temporal perspective reveals that the digitalization-sustainability relationship is not static but progresses through identifiable stages, each characterized by different types of interactions and organizational responses. Our study also advances theoretical understanding of the complex nature of sustainability in digital transformation by demonstrating how different sustainability dimensions interact with digitalization processes. In particular, our research extends beyond the predominant environmental focus (Chen *et al.*, 2020), by providing evidence of how organizations can leverage digital technologies to address multiple sustainability dimensions. We show distinct patterns in how economic and social sustainability dimensions intersect with digitalization initiatives. Specifically, we show that economic sustainability often creates initial intersections with digitalization through projects like PLM and Zero Defect, while social sustainability emerges through initiatives such as Digital Talk and Digital Training. Thus, our findings demonstrate that achieving comprehensive digital-sustainable interaction requires attention to all three sustainability pillars, though these may develop and interact with the firm's digitalization journey at different paces and through different mechanisms. In this sense, it emerges that economic sustainability often forms the initial bridge with digitalization, social sustainability emerges through organizational learning and capability development, and environmental sustainability requires more deliberate integration efforts.

Second, it contributes to the business network (IMP) approach, and particularly to the research stream dealing with technological development and environmental sustainability (Strömsten and Håkansson, 2007; Håkansson and Waluszewski, 2013; Baraldi *et al.*, 2011). It does so by providing holistic analysis encompassing different dimensions of sustainability (not only environmental but also social and economic) and by exploring how actors engage in sustainable practices, how they allocate resources for digital activities and how activities fostering sustainability and digitalization are undertaken. In particular, the study shows how the relationship with key external actors (customers, local consulting companies, technology providers) fosters the emergence of digitalization-sustainability intersections and how manufacturing companies manage them to create a digital-sustainable interaction (Lichtenthaler, 2021). Specifically, we provide a contribution to the activity layer of the ARA framework in the context of digital-sustainable transformation, by identifying "bidirectional" and "multi-intersection" activities. The former refer to activities that originate in one journey (digitalization or sustainability) but create reciprocal effects that contribute back to their origin, the latter to activities specifically designed to serve multiple purposes across both the digitalization and sustainability journeys.

From a managerial standpoint, the case of *Beta* offers insights for manufacturers with digitalization and sustainability as key strategic objectives. First, a significant outcome of the research emphasizes the importance of the decision-making process for digital and sustainable strategies. Specifically, it is noteworthy to note that initial planning of digitalization- and sustainability-related initiatives is crucial to understanding how to facilitate

the interaction between the two. Developing awareness of the necessity to combine digital and sustainable initiatives "ex-ante" can facilitate the overall process. Managers aiming to achieve this goal could rely on the ARA framework, integrating actors, activities and resources in their strategic vision to arrive at optimal solutions. Table 2 serves as an effective tool in this regard. Not only, but managers should also pay particular attention to the strategic development of the network of actors involved in the 'Digitainability' process. While sustainability objectives often follow an "outside-in" logic, digitalization goals are frequently tied to an "inside-out" approach. The misalignment between these two approaches could lead to conflicts or inefficiencies along the value chain. Therefore, it is advisable to allocate resources toward finding partners who can support both sustainability and digitalization objectives, ensuring efficiency and coherence within the business network. Second, the research highlights how, when "ex-ante" reasoning is not feasible – perhaps due to the occurrence of digital and sustainable journeys at different points in time, managers can still make efforts to integrate them "ex-post". In such cases, planning new activities that belong to the "bidirectional" or "multi-intersection" type can be valuable. This approach accelerates the achievement of digital-sustainable interaction and helps limit resource consumption. For this purpose, the role of HR becomes crucial. Human resources, given their constant responsibility for the organizational management of employees, are naturally inclined to achieve ethical, social and environmental sustainability goals in various ways. Through appropriate training of HR personnel, these sustainability objectives can be easily aligned with digitalization goals, making HR the central function for coordinating "multi-intersection" activities within the organization.

Third, this study underlines the importance for companies aiming to achieve digitalization and sustainability goals to adapt their organizational structure to an emerging model of "Digitainability". The observed case study emphasizes how the absence of a strategic digital/sustainable reference point within the corporate organizational structure can accentuate the divide between digital and sustainable paths, thereby increasing costs and inefficiencies. To avoid such dynamics, companies may consider, after an initial phase of experimenting with both journeys, integrating a corporate function dedicated to the development of digital and sustainable practices. This integration would facilitate the synergistic and unified development of activities, investment in resources and engagement of actors for both digital and sustainable trajectories.

This study has certain limitations that, nonetheless, can serve as valuable insights for further research on the addressed topic. The limitations primarily stem from the chosen data collection methods. While the combination of sustainability reports and interviews provides a detailed understanding of the case, it's important to note that the number of interviewed actors was limited to the most relevant ones. Conducting additional research with a more extensive focus on various actors could prove beneficial in enhancing our understanding of the interaction between digitalization and sustainability.

Furthermore, the utilization of a single case study proved particularly valuable in facilitating an in-depth and fine-grained analysis of this emerging phenomenon. However, for a more comprehensive perspective, future research could explore similar dynamics in other sectors within the manufacturing industry. For example, investigating whether industries facing specific constraints, such as the textile industry regarding sustainability, allow for interaction between digital and sustainable efforts to create additional value for customers would be of interest.

Finally, this article does not delve into the potential impact of the most recent and cutting-edge technologies on the interaction between digitalization and sustainability. Future research could explore the role of Artificial Intelligence, considered as a central element of "Industry 5.0," and assess its feasibility in conjunction with sustainability initiatives.

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